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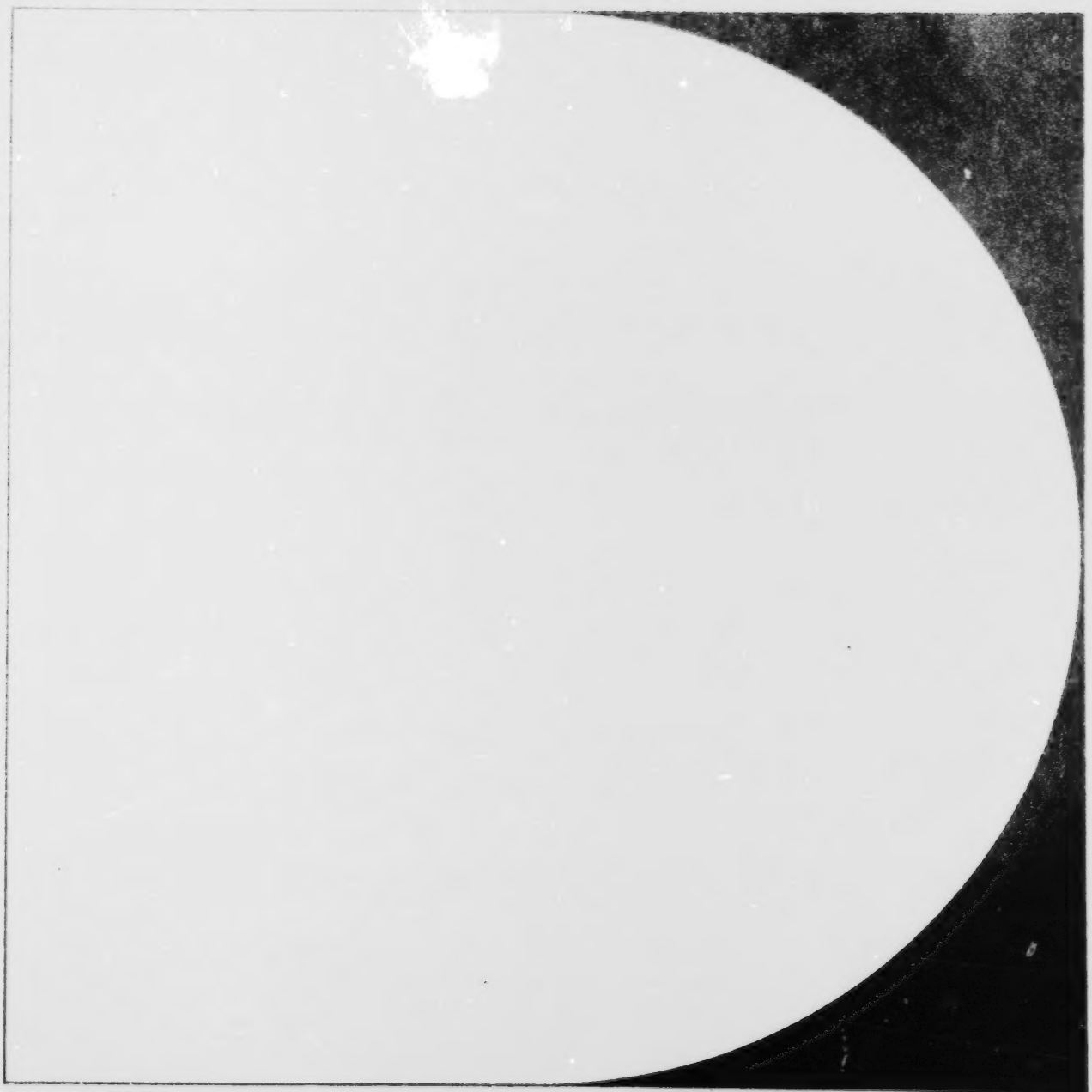

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EVALUATION OF ALTERNATIVES TO OIL IGNITION FOR COAL FIRED BOILERS

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CONTRACTOR: ONTARIO HYDRO

Prepared by: _____
T.B. Walls, P. Eng
Design Specialist

Reviewed by: _____
S. Legedza, P. Eng
Supervising Design Engineer

Approved by: _____
A.G. Barnstaple
Process and Development
Engineer

MAR 15 1985

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ABSTRACT

This study is an assessment of the undernoted alternatives to No. 2 oil from ignition of coal in coal fired boilers:

(a) Coal Oil Mixture
(b) Plasma Arc Ignition
(c) Natural Gas
(d) Direct Ignition of (Stored) Pulverized Coal;

- Combustion Engineering System
- Steinmuller System

Other ignition alternatives are also briefly discussed. Two specific Ontario Hydro generating stations were used for the study; Nanticoke GS, 8 x 500 MW units with Babcock and Wilcox boilers, Lambton GS, 4 x 500 MW with Combustion Engineering boilers.

The economic comparison of alternatives is conservative especially where there are some doubts as to the overall capability and/or reliability of one alternative. Some assumptions have been necessary, the frequency of ignition, the escalation of different fuel prices and the availability of each system.

The study findings show that while three of the alternatives - (a) natural gas, (b) coal oil mixture, (c) plasma arc (partial) - in that order, do in fact appear to offer lower lifetime costs in some cases than continued use of No. 2 ignition oil, there is insufficient incentive at the present time to implement such systems because of the relatively long payback periods.

EXECUTIVE SUMMARY

This study is an assessment of possible alternatives to light oil for coal fired boiler ignitions in a retrofit application. However, of all the alternatives pursued, only one - natural gas - is seen as being able to eliminate the use of oil altogether. Other alternatives are considered to require significant (up to 60 percent, see page 3) amounts of oil due to various inadequacies and/or uncertainties. Many assumptions have been made in this regard.

Alternatives considered for evaluation (in one or more forms):

(a) Coal Oil Mixture
(b) Plasma Arc
(c) Natural Gas
(d) Direct (or Stored) Coal Ignition

Some other possibilities considered - but not evaluated are discussed in Appendix VI.

For study purposes two generating stations were selected:

(a) Lambton GS 4 x 500 MW Combustion Engineering boilers
(b) Nanticoke GS 8 x 500 MW Babcock and Wilcox boilers

As future ignition fuel requirements can only be predicted, two estimates of consumption, a high and a low range are used as scenarios for economic evaluation. It is considered that actual ignition fuel requirements will almost certainly fall within this range.

A reproduction of the economic summary table is shown over for the reader's benefit. The lifetime costs are present worthed capital and operating costs. As shown in the table, none of the alternatives evaluated could be economically justified at Lambton GS. With the present Nanticoke GS operation however, natural gas, coal oil mixture and plasma arc (partial) in that order, show a positive return on investment. They have long payback periods however which could only be justified on the basis of reducing dependence on oil.

Some sensitivity to the above has been determined by calculating the lifetime costs of the oil and the leading alternatives at a new 4 x 500 MW generating station. This time the capital cost of the ignition system is included in the lifetime costs of oil. As shown in Table 8.2, there is only a slight improvement in the alternatives over oil.

The conclusions of this report are that natural gas is the most feasible and viable alternative to ignition oil. This applies primarily to new generating stations. Retrofitting existing stations can only be done on the basis of reducing dependence on oil.

ECONOMIC SUMMARY

	LAMBTON GS				NANTICOKE GS			
	High Ignition		Low Ignition		High Ignition		Low Ignition	
	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years
	x 10^3		x 10^3		x 10^3		x 10^3	
Existing Oil								
Capital	0	N/A	0	N/A	0	N/A	0	N/A
Fuel (annual)	1,526		468		5,820		3,050	
OM&A (annual	36		25		107		86	
TOTAL LIFETIME PW	20,878		6,522		97,894		51,611	
Coal Oil Mixture								
Capital	10,744	20+	10,744	20+	15,920	12	15,920	21
Fuel (annual)	1,132		352		4,306		2,258	
OM&A (annual)	71		50		214		171	
TOTAL LIFETIME PW	23,268		13,265		80,490		48,591	
Plasma Arc - Total								
Capital	45,621	20+	45,621	20+	75,938	24+	75,938	24+
Fuel (annual)	852		301		3,431		1,885	
OM&A (annual)	33		23		100		80	
TOTAL LIFETIME PW	45,557		39,375		109,730		87,669	
Plasma Arc - Partial								
Capital	17,703	20+	17,703	20+	33,703	18	33,703	24+
Fuel (annual)	1,025		335		4,057		2,154	
OM&A (annual)	34		24		104		83	
TOTAL LIFETIME PW	26,205		17,790		89,226		60,115	

Cont over

ECONOMIC SUMMARY

	LAMBTON GS				NANTICOKE GS			
	High Ignition		Low Ignition		High Ignition		Low Ignition	
	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years
	x 10^3		x 10^3		x 10^3		x 10^3	
Natural Gas								
Capital	10,721	18	10,721	20+	15,486	9	15,486	14
Fuel (annual)	1,014		309		3,882		2,034	
OM&A (annual)	31		21		91		73	
TOTAL LIFETIME PW	20,108		11,946		67,083		40,934	
Direct Coal Ignition	CE System				Steinmuller System			
Capital	33,257	20+	33,257	20+	57,607	23	57,607	24+
Fuel (annual)	831		233		3,435		1,736	
OM&A (annual)	166		116		288		230	
TOTAL LIFETIME PW	35,272		27,689		92,244		68,585	

COAL FIRED BOILER IGNITION - EVALUATION
OF ALTERNATIVES TO OIL

TABLE OF CONTENTS

		Page No.
	EXECUTIVE SUMMARY	
1.0	INTRODUCTION	1
1.1	List of Alternatives Considered for Study	1
1.2	Assumptions Used for Study	1
1.3	Generating Station Details	3
2.0	COAL OIL MIXTURE	5
2.1	Introduction	5
2.2.	Process Description	6
2.3	List of Advantages and Disadvantages	10
2.4	Discussion of Developmental Issues and Problems	11
3.0	PLASMA ARC IGNITION	13
3.1	Introduction	13
3.2	Process Description	14
3.3	List of Advantages and Disadvantages	19
3.4	Discussion of Developmental Issues and Problems	19
4.0	NATURAL GAS	21
4.1	Introduction	21
4.2	Conversion Description	21
4.3	List of Advantages and Disadvantages	22
5.0	DIRECT IGNITION OF PULVERIZED COAL (COMBUSTION ENGINEERING SYSTEM)	23
5.1	Introduction	23
5.2	Process Description	23
5.3	List of Advantages and Disadvantages	28
5.4	Discussion of Developmental Issues and Problems	29
6.0	STEINMULLER SYSTEM	30
6.1	Introduction	30
6.2	Process Description	31
6.3	List of Advantages and Disadvantages	38
7.0	ECONOMIC EVALUATION	39
7.1	Capital Costs	42
7.2	Operating Costs	47
7.3	Total Lifetime Costs	50

LIST OF TABLES

		Page No.
TABLES		
	Economic Summary	
1.1	Ignition Oil Consumption	2
1.2	Anticipated Range of Oil Displacement by Alternatives	3
7.1	Economic Summary	40
7.2	COM System Capital Costs	43
7.3	Capital Costs of Plasma Arc Alternatives	44
7.4	Capital Costs of Natural Gas Alternatives	45
7.5	Capital Costs of Two Combustion Engineering Direct Ignition Systems for Lambton GS	46
7.6	Capital Costs for Two Steinmuller Systems Retrofitted to Nanticoke GS	47
7.7	Operating Maintenance and Administration Estimates	48
7.8	Total Annual Energy Requirements of Ignition Alternatives	49
7.9	Ignition Alternatives - Lifetime Costs	50
8.1	30 Year Lifetime Costs for New Station Ignition Systems	53
8.2	Summary of Advantages and Disadvantages	54
APPENDICES		
I-1	Operating Maintenance and Administration Estimates	61
II-1	Ignition Oil Quantities and Start Up Times	64
II-2	Ignition Oil Heat and Electrical Energy	66
II-3	COM - Total Energy Requirements	67
II-4	Total Plasma Arc Conversion - Total Energy Requirements	73
II-5	Partial Plasma Arc Conversion - Total Energy Requirements	74
II-6	Total Energy Requirements of Two Combustion Engineering Systems at Lambton GS	78
II-7	Total Energy Requirements for Two Steinmuller Systems at Nanticoke GS	81

LIST OF FIGURES

		Page No.
Figure 1	Diagrammatic Arrangement of Coal Oil Mixture System	7
Figure 2	Plasma Torch in Lance Assembly in Low NO_x Burner in Nanticoke Unit 6	16
Figure 3	Westinghouse Plasma Torch With and Without Protective Cover	17
Figure 4	Cross Section of Plasma Lance	18
Figure 5	Combustion Engineering System	24
Figure 6	Combustion Engineering Burner Arrangement at Lambton GS	26
Figure 7	Combustion Engineering Modifications to Lambton GS Windbox	27
Figure 8	Sketch of Nanticoke GS Circular Coal Burner and Oil Igniter	32
Figure 9	Steinmuller System for Four Boilers at Nanticoke GS	33
Figure 10	Steinmuller PF Coal Igniter	36
Figure 11	Effect of Air Preheat on Ignition Time of PF Particles	37

1.0 INTRODUCTION

Light oil is the conventional choice for lighting up pulverized coal fired boilers. This oil is the fraction of crude oil which has neither the hazardous volatility of propane, gasoline etc., nor the high viscosity of heavy bunker oil. The light oil used for ignition purposes at Ontario Hydro's thermal generating stations can be stored in simple storage tanks and pumped through unheated pipelines summer and winter.

However, oil supplies are finite and have become more noticeably so since the OPEC embargo of 1973. This embargo has also dramatically raised the price of oil. It is considered by virtually all forecasters that the cost of oil will continue to escalate in real terms over the long term.

With this situation, it is clearly advantageous to find an alternative ignition fuel, if it is demonstrated as technically feasible and economically viable.

In Ontario Hydro's circumstances the validity of this statement is becoming increasingly relevant as the coal fired units change from a base load or continuous type of operation to that of a two shifting or, on and off daily, type of operation. This change arises from the introduction of more nuclear generating units which are preferred for base load operation because of lower operating costs.

Some difficulty has been encountered in obtaining information on the new ignition systems. Manufacturers have been guarded in releasing information on at least two accounts - the uncertainties arising from unproven equipment and also the desire to maintain trade secrecy.

1.1 List of Alternatives Considered for Study

In this study four alternative approaches to direct ignition oil have been considered.

(a) Coal Oil Mixture
(b) Plasma Arc
(c) Natural Gas
(d) Direct Coal Ignition (Combustion Engineering and Steinmuller Systems)

Other ignition alternatives were also noted but not pursued. A brief description of these other possibilities is given in Appendix V.

1.2 Assumptions Used for this Study

Generating Station

Only Lambton GS and Nanticoke GS have been considered for this study. These stations are considered to have at least 20 years of remaining operating life.

Originally, Thunder Bay GS was also considered for the study. This station had to be dropped however as manufacturers declined to bid their systems at Thunder Bay GS.

Ignition Oil Requirements

Nobody can forecast exactly how much ignition oil will be required in the years to come. Therefore two scenarios representing the views of two different schools of thought, have been adopted. These are referred to as a high ignition scenario and a low ignition scenario. The total requirements presented in Table 1.1 are considered to be possible and not extreme limits of use for ignition oil. A more comprehensive breakdown is given in Appendix II.

TABLE 1.1

Ignition Oil Annual Consumption

	Scenario	
	Low Ignition kL/Yr	High Ignition kL/Yr
Lambton GS	1977	6477
Nanticoke GS	12996	24808

Scope of Conversion

The intent at the outset of the study was to consider complete replacement of ignition systems for an economic comparison. This has been adhered to as far as possible. However, it was soon realized that this was impractical especially with the plasma arc system where very high capital costs result when considering a total conversion. However for the record the plasma arc total conversion is reported here along with a partial conversion. This partial conversion calls for plasma arc igniters to be fitted to the burners from two pulverizers which is the mimimum number of pulverizers which can normally operate without support oil. It is assumed (perhaps optimistically) that this set up could be used to bring the boiler on and build up load - if both of these particular pulverizers are available.

The Combustion Engineering and Steinmuller system were also found to have limitations. Neither of these systems eliminate oil ignition but largely eliminate the use of oil for boiler warm up.

The actual displacement of oil anticipated is somewhat subjective on all of the alternative ignition systems other than natural gas. Details on the fuel estimates used for this study are given in Appendix II and a summary is shown in Table 7.7 in the Economic Comparison. Table 1.2 below highlights the anticipated range of oil displacement which could be achieved by the various ignition alternatives.

TABLE 1.2

Anticipated Range of Oil Displacement by Alternatives

Alternative	Oil Displacement %
Coal Oil Mixture	40-42
Plasma Arc (Total)	65-85
Plasma Arc (Partial)	50-70
Natural Gas	100
Combustion Engineering	72-80
Steimuller	66-75

Assumptions Used for Economic Comparison

The complete list is located in Section 7; the following are the major ones.

Discount rates and forecasts of escalation as per Ontario Hydro Economics Division February 1984 predictions. Fuel costs and escalation as per Ontario Hydro Fuels Division - Spring 1984.

Eighteen and 24 years remaining plant life available for alternative ignition system at Lambton GS and Nanticoke GS respectively.

1.3 Generating Station Details

Lambton GS

Location — 24 kilometres south of Sarnia on the east bank of the St. Clair River.

Size — 4 x 510 MW

Fuel — US eastern bituminous high volatile (30 percent) coal.

Boilers — Combustion Engineering Superheater Ltd Double furnace, radiant superheater and reheater, single drum, controlled circulation.

Maximum continuous rating (MCR)
Main steam 453.6 kg/sec 16.9 MPa, 538°C
Reheat steam 422 kg/sec 4.0 MPa, 538°C
Fuel flow 45.86 kg/sec
Six Raymond bowl mill pulverizers 12.1 kg/sec (1 spare).

Burners	Tangential fired 48 CE circular nozzle coal burners in six elevations (up to 1.5 kg/sec each) 48 side oil igniters 52.9 mL/sec of No. 2 oil each (electric spark ignition).
Turbines	General Electric Company Four cylinder tandem compound 3600 rpm.
Emission Control	Joy Manufacturing Company Electrostatic precipitators Design collection efficiency 99.5 percent.
In service dates	Unit 2 1969 Units 1, 3 and 4 1970

Nanticoke GS

Location	North shore of Lake Erie a few kilometres east of mid-point.
Size	8 x 505 MW
Fuel	Designed for US eastern bituminous high volatile (30 percent) coal but presently burning a 50/50 blend of 35 percent volatile US and Western Canadian bituminous coal. The Western Canadian coal is itself an equal mixture of 33 percent volatile and 20 percent volatile coal.
Boilers	Babcock and Wilcox Ltd Front and rear wall firing, natural circulation. Radiant, drainable superheater and reheater. Maximum continuous rating (MCR) Main steam 453.6 kg/sec 16.9 MPa 538°C Reheat steam 415 kg/sec 4 MPa 538°C Fuel flow 48.8 kg/sec (50/50 blend) Five B&W ball race pulverizers 11.3 kg/sec (no spare)
Burners	24 front wall B&W circular coal burners (three rows) 16 rear wall B&W circular coal burners (two rows) (1.4 kg/sec of coal/burner) 40 oil igniters (one per coal burner) Electric spark ignition. 128 mL/sec of No. 2 oil each.
Turbines	James Howden and Parsons Ltd Four cylinder tandem compound 3600 rpm.
Emission control	Joy Manufacturing Company Electrostatic precipitators Design collection efficienty 99.5 percent.

2.0 COAL OIL MIXTURE (COM)

2.1 Introduction

The idea of burning coal oil mixture is not new and dates back decades. Today, the main thrust behind coal oil mixture (COM) technology is to obtain a fuel which is less expensive than oil but can be burned in boilers designed for oil firing. Practical research on the matter is being conducted world wide, especially in Europe and Japan where high energy costs exist. In North America most interest has been with bituminous coal and No. 6 oil. Due to lack of economic incentive in power generation, however, interest is waning.

There have been problems with burning COM - burner tip erosion, mixture stability, and handling - however it can be argued that basically the successful combustion of COM is attainable, and has been demonstrated on a commercial scale. The main stumbling block against conversion to COM is not physical, but economical. Escalation of oil prices has ceased - if momentarily. Also in many cases utility load growth is slowing, and in so doing, have effectively lowered many generating plant capacity factors. With this situation it becomes difficult to economically justify a conversion from oil burning to COM. Many authorities have publicly stated that the investment required is not worth the risk. It is presently considered that in North America at least, the main scope for COM lies with industrial boilers where extensive coal conversions simply can not be done. However, some oil fired generating plants have constraints which will probably enforce a COM conversion regardless of economics. For example, generating stations situated on small sites surrounded by sensitive (e.g. residential) areas. Such stations cannot have coal piles and the most obvious way to reduce fuel costs would be to convert to COM - a fuel which can be freighted in. Another option for a generating station with such restraints is coal water mixtures. This would be an even lower cost fuel, but has the problem of incurring a unit derating. Each case would have to be optimized independently.

CWM is being tested as a boiler fuel in Eastern Canada. In April 1982 an agreement was signed between Energy Mines and Resources Canada, New Brunswick Power and Cape Breton Development Corporation to test a CWM at New Brunswick Power's Chatham plant. A Swedish company, A.B. Carbogel, has been contracted to manufacture the CWM fuel. It is hoped that the program will successfully demonstrate all aspects of CWM combustion - fuel production and consistency fuel handling, burner design and boiler operation. Tests are presently ongoing and not without difficulties. A report is anticipated in early 1985.

Ontario Hydro has researched COM, and actual pilot tests have been conducted at generating stations. Emphasis was placed on mixtures with No. 2 oil for ignition use rather than No. 6 oil in coal oil mixture, as would be required for fuel conversion of an oil fired boiler. The pilot tests were actually carried out with a full scale ignition burner (from

Lakeview GS) in a cold boiler at RL Hearn GS COM for the test program was manufactured by the University of Toronto. In general, the testing was regarded as successful in demonstrating the suitability of COM as an ignition fuel. The process adopted for this study is based on this developmental work.

A possible alternative to manufacturing COM would be to purchase coal oil mixture from a supplier. Coaliquid Incorporated, a subsidiary of the McDonnell Douglas Corporation has expressed an interest in constructing a processing plant in Southern Ontario which could supply ignition fuel requirements for Lambton and Nanticoke generating stations. This alternative could reduce the capital requirement by about $1.6 M at Lambton GS and $2 M at Nanticoke GS. There would also be a substantial saving in OM&A. However all of these gains would soon be negated by the 25 percent differential in constituent coal and oil price versus the Coaliquid Inc COM product price.

2.2 Process Description

The COM used for study purposes consists of the following:

	% by weight
US eastern bituminous coal	50
Water	5
No. 2 oil	45

Other parameters of COM as measured by Ontario Hydro:

Density	1.02 kg/litre
Heating Value	35 200 kJ/kg*
Viscosity	
- low shear	1 000 centipoise at 25°C
- high shear	500 centipoise at 25°C

The viscosity is quoted at 25°C which has been adopted conceptually as the operating temperature of the COM being supplied to the ignitors.

For study purposes, the following conceptual scheme, outlined diagrammatically in Figure 1 is used for price estimating. It is assumed that the total heat requirement from COM is identical to that provided at present by No. 2 oil. All aspects are considered proved although possibly not fully optimized. Minimal redundancy is assumed at the outset. The COM scheme however, is considered to completely supplant the existing ignition oil system complete with a new pipe transfer and distribution system. New piping is considered necessary as COM is not suited to drops in vertical sections of pipe.

* Calculated

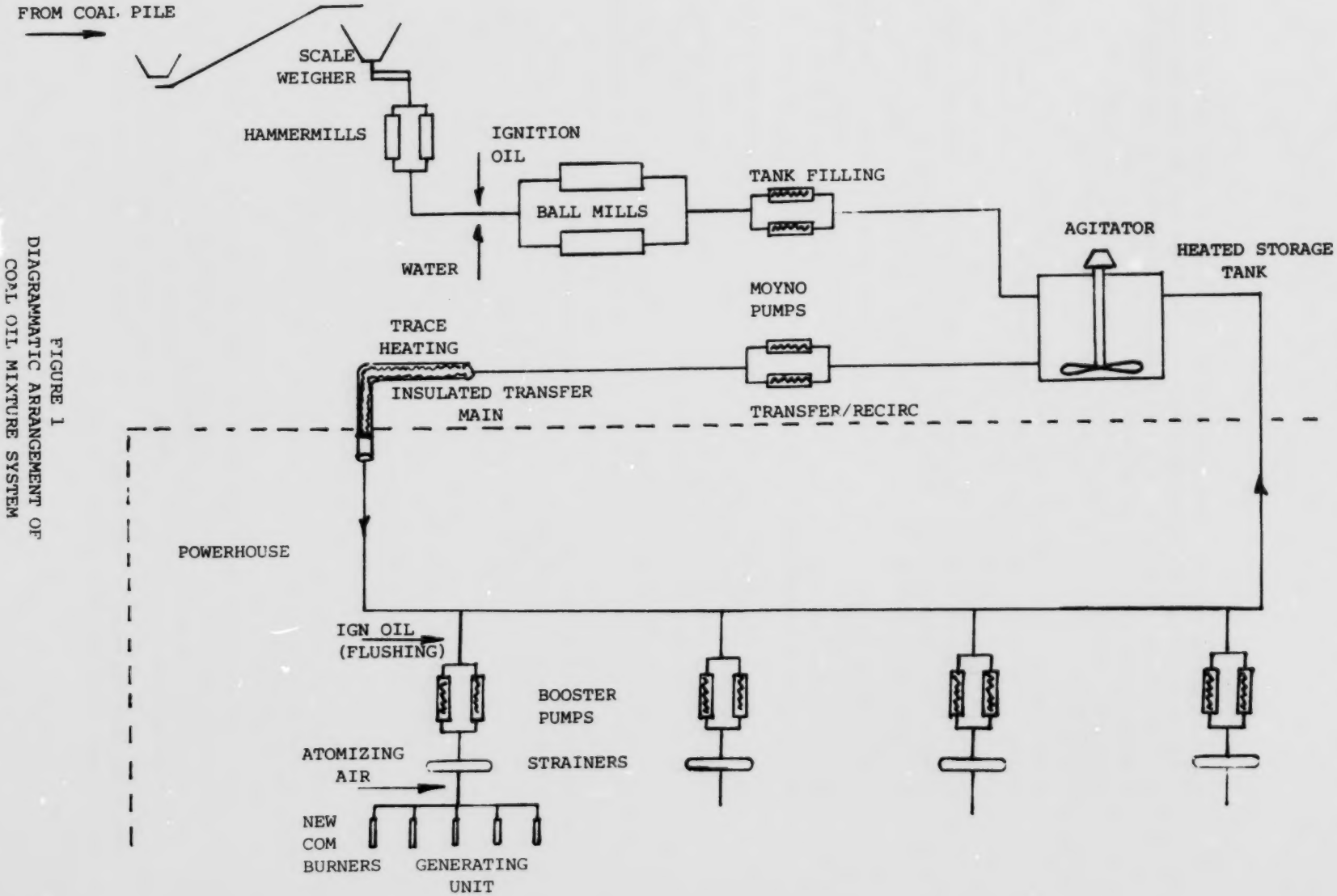

FIGURE 1
DIAGRAMMATIC ARRANGEMENT OF COAL OIL MIXTURE SYSTEM

Despite the new piping, some plugging of COM lines is still anticipated. It is anticipated that for most occasions the lines can be cleared with the use of pure ignition oil. An allowance of 5 percent of the quantity of existing ignition oil is adopted for this purpose in each scenario. An imminent plugged line situation should be detectable by pressure measurement as well as obvious reduction of burner output.

An adequate strainer system with full redundancy is required for the COM system. The filter size of the strainers would be just a size smaller than the burner tip holes. It is anticipated that a fairly continuous on/off flushing will be required. Perhaps the best approach would be to have the strained material at these periods dumped on to the coal pile. It is anticipated that the virtually "all oil" flow passing the strainers during flushing can be successfully burned by the COM burners.

Coal is brought from the station coalpile to the new COM production house by mobile equipment. The mobile equipment dumps the coal into a ground level hopper from where it is conveyed by a bucket type conveyor to a small elevated bunker which is used to feed the pulverizer.

US coal has been adopted for COM production, as it is superior to Western Canadian coal in most respects and it is readily available at both Lambton GS and Nanticoke GS. It will also be available throughout the life of the plant unlike Western Canadian coal which could cease in 1992.

One special attraction of the US bituminous coal that Ontario Hydro uses, is the consistently low inherent moisture content. This is always below one percent. Other aspects of US coal which make it very compatible with COM production are, its lack of extreme hardness, high heating value, low ash and water content, and a low fusain fraction. Fusain is a soft fibrous material in coal which is largely responsible for all staining caused by coal. However, although fusain has this ability to dirty hands etc., it is not very reactive as far as COM and combustion are concerned.

Two types of grinding are possible for the coal - wet grinding or dry. Wet grinding calls for grinding the coal with the requisite quantities of water and oil which give the desired COM. At this point in time this is the preferred alternative as a) it is considered to be lower capital and operating cost than dry grinding where a cyclone and baghouse arrangement is required to catch the fines, b) it is inherently safer, and c) wet grinding is seen as being more compatible with future automatic control of the process.

Although not considered here at this time, wet grinding has another possible benefit. It would be possible to incorporate an oil agglomeration process with wet grinding. This would greatly improve the fuel quality by lowering the amount of mineral matter which in turn would lower the particulate emissions. However, this action would considerably increase the capital and operating costs (Ref 11) and is not considered justifiable for an ignition (only) fuel.

Whether dry or wet grinding is used the coal will be ground down to 80 percent smaller than 74 microns. For this study, it has been assumed that this will be accomplished by using a ball mill with a wet grinding process. This has only been achieved on a pilot plant scale in North America but has been developed to a commercial scale (10 Mg/hr) in Japan (Reference 8).

Another possibility is the Szego mill. This is a stationary cylinder containing helical grooved rollers for grinding the coal. However, the mill is still developmental as nobody has used one on a large scale commercial operation. Ball mills have been selected as the basis for this study as they are more conventional and because they are higher in capital cost. With a new process such as COM there has to be a degree of conservatism in developing capital costs. However it is possible that the Szego mill could be viable at some point in the future.

Water is added to the mixture to give some stability to the suspension of pulverized coal and to improve reconstitution of the COM when necessary. Without water (or other more expensive stabilizing agent), fallout of coal from No. 2 oil is extremely rapid - at least for the size of grind considered here. The addition of water has also been demonstrated as preventing caking of the coal when long term settling does occur. In the presence of water the settled coal lies in soft sedimentary deposits at the bottom of the tank. A 5 percent water in COM is considered adequate to give all the benefits without suffering too much from the drawbacks from even higher water contents, e.g., lowering the combustion efficiency, increasing the corrosion potential, etc. It is also possible that this water may be beneficial in burner atomization of the COM. As the COM passes through the burner tip the water is instantly vapourized with a resultant leap in volume thus compelling expansion of the jet from the tip and hence the atomization.

Not all of the effects of water in the COM are fully understood. It is considered however that the water when dispersed, forms static charged particles. Another possibility is a partial emulsion forming between the oil and water. Whatever the reason(s), the properties of COM are demonstrably changed by the addition of small quantities of water - notably the increase of stability and viscosity.

There are slight drawbacks to water in the COM. Probably the most awkward one is having to continually check the coal moisture content in order to maintain a reasonably constant water content in the COM. Although the inherent moisture could be assumed constant at say 0.7 percent, it would still be impractical to actually check the total moisture content of the coal. This will be done by inference. The COM product would be monitored for moisture content and the water supply adjusted accordingly. Also, as indicated above, having water in a COM increases the viscosity, thus increasing pumping costs. Finally, greater precautions would be required to prevent corrosion in storage and piping systems etc., due to the increased potential arising from the 5 percent water content in the COM.

Once mixed, the COM is put into a storage tank. The tank is sized for two days of pulverizer production or maximum conceivable daily consumption plus 20 percent. It is assumed that the COM replaces ignition oil directly on a heating value basis. Further, for equipment sizing it is assumed that the maximum daily consumption would not exceed one warm start/day per generating unit plus one hot start per station/day (see Table Appendix II-1, also COM section). This arrangement would permit eight cold/warm starts at Nanticoke GS on a Monday morning after a weekend shutdown.

Agitator/stirrers in the storage tanks keep the COM properly mixed continuously. The rubber covered agitators are slow speed 56 rpm and 25 rpm (Nanticoke and Lambton respectively) but rated at identical torque for each application. Each agitator is a single four blade turbine with blades inclined at 45°. The diameter is approximately one third of the storage tank in each case. The storage tanks, which are located outdoors, are electrically heated by external surface padding and insulated by 7.5 cm of fibre glass complete with aluminum cladding.

Moyno progressing cavity pumps have been adopted for both transfer of COM to the boilerhouse and for individual boiler supply to burners. The individual boiler distribution/pumping system is assumed to be uninsulated as is the present ignition oil piping system.

The new COM pipelines will be of similar dimensions to the existing oil lines. However there will be differences. Large vertical drops will be avoided. Also there will be no tight radii bends. The minimum design velocity of the COM is considered to be 0.4 - 0.6 m/sec for the small pipes about the boiler and about 1 m/sec for long transfer pipes. However it is better practice to use about 1.6 m/sec in each case. Shutdown of the pipeline while COM is being pumped is possible providing that (a) excessive pressure surges are avoided when restart the COM flow and (b) the shutdown period does not exceed about three hours. In this latter event the pipe would have to be drained and/or flushed out.

Finally, new burners and tips capable of handling COM would be installed.

2.3 List of Advantages and Disadvantages

Advantages of COM

(a) Combustion and ignition using COM are considered feasible and generally proven (References 9-11).

(b) COM could provide flame support and all ignition sequences as does ignition oil at present.

(c) Other than preparation and initial handling, COM operation is similar to existing ignition oil operation.

Disadvantages of COM

(a) The operating (fuel) cost of this alternative is high. Only 42 percent* of the ignition oil can be replaced, thus reducing the opportunity for payback. Strainer flushing and COM system breakdown would further reduce this percentage.

(b) A COM system is not as straightforward as a push button ignition oil system. Continued care and supervision is required due to the potential for processing and handling difficulties.

(c) COM pipelines should be as short as possible to minimize the risk of plugging. This is not possible at very large thermal generating stations, especially the 4 000 MW Nanticoke GS.

(d) Commercial scale demonstration is required before a generating station would have a complete ignition system conversion from No. 2 oil to COM. In any ignition system, reliability is of paramount importance. There are still doubts about its use in cold start conditions.

(e) Start up particulate emissions would be much higher with this ignition fuel than the existing oil.

2.4 Discussion of Developmental Issues and Problems

Considerable research into burning COM is ongoing. Various coals are being tried. One approach calls for micronization of the coal - pulverizing it down to say 15 microns versus the 74 microns achieved for conventional pulverized coal firing. This ultra fine grinding is anticipated to improve the stability of a COM, and give improved atomization. The effect on viscosity is uncertain.

Other approaches to improve the stability and viscosity characteristics are the addition of water and other additives. These additives are not specified as manufacturers insist it is proprietary information and is necessary for successful operation with COM.

Burner tip is probably the most developmental area in COM combustion. Designing and manufacturing a tip which will successfully burn COM is relatively easy, but making one that will last for a long time is difficult. In fact, boiler manufacturers are still having considerable

* By definition the COM considered from this study consists of 45 percent oil and 50 percent coal by weight. However, if an identical total heat for ignition is required from COM as is supplied by the existing oil, more litres of COM are required due to the lower heat content per litre. The arithmetic result of this adjustment corresponds to a 42 percent reduction in total ignition oil consumption ignoring oil flushing periods, etc.

difficulty in producing a tip which will stand up to the erosive nature of COM. Research is ongoing into various materials - stellite, ceramics etc. It may be however that the answer is a compromise - a relatively inexpensive tip which must be replaced at frequent intervals.

Good burner operation is more critical with COM than with straight oil. As the burner deteriorates, problems compound. The flame noticeably worsens, and the carbon in ash escalates rapidly, thus becoming much more visible. This is particularly bad during start up when the electrostatic precipitator is not in service. With this situation other problems also emerge. The incidence of sticky deposits increases. Also, combustion efficiency is lowered.

No matter how successful tests are with pipelining of COM, it must be taken for granted that in a normal operation situation, pipelines will suffer from plugging. At this point in time it is assumed that simple oil flushing will clear plugged lines. Compressed air may also achieve line clearing. However, even stronger clearing methods may be required.

The wet grinding discussed in the process description is a reality in that it has been achieved. Again however, this achievement is under laboratory type controlled conditions. Some developmental work is almost certainly required to achieve the required grinding and mixing on a day-to-day basis.

Finally, it may be discovered that COM storage tanks require more than agitation. Conceivably they could require an annual evacuation to remove a slowly increasing solids residue at the bottom of the tank.

3.0 PLASMA ARC IGNITION SYSTEM

Only coal ignition at the boiler main burners is discussed here. A later idea using plasma arc to pyrolyze coal into a gaseous fuel suitable for ignition is discussed in Appendix V.

3.1 Introduction

Babcock & Wilcox are actively pursuing plasma arc ignition technology as one of several options to reduce ignition oil requirements.

Plasma arc devices have been in existence throughout the twentieth century and have been further developed by aerospace researchers in the early nineteen sixties. A major aspect of this work has been the investigation of the effects of high temperature on materials used for rockets, etc. Now the plasma arc technology is being applied to ignition of pulverized coal; however, the application of this concept is tenuous at the present time.

Now the plasma arc technology is being applied to the pulverized coal ignition. The application, of this concept is still developmental.

The actual plasma flame is created by passing air between a pair of electrodes energized by 100-150 kW of power. By definition, a gas is in the plasma state when all of its molecules are in a dis-associated state and the atoms are at least partly ionized. What this calls for in more physical terms is a gas at a temperature in the order of 8 000°C. This plasma temperature is much higher than the flame from an oil ignitor (although the plasma flame is not nearly so large and all encompassing as is the oil flame), and is capable of igniting pulverized coal or maintaining flame stability during difficulties with coal feeding etc.

Initially, Babcock and Wilcox thought that the plasma arc would ignite the coal even under cold start conditions. However, this idea has been abandoned after some discouraging results in early testing. It is now conceded that ignition oil must be used to bring the boiler up to hot or at least warm start conditions before attempting to use the plasma arc ignition system (PAIS).

Presently, Babcock and Wilcox are experimenting with plasma arc torches using 100-150 kW of electricity. It is claimed that this input is only a very small percentage (three to five percent) of the input required from oil burners. It is further claimed by plasma arc torch manufacturers, that the efficiency of energy conversion, electrical to heat energy is 80-90 percent plus, once the arc is optimized for the duty involved.

Actual plasma arc ignition testing (in the Ontario Hydro system) was first carried out at Lakeview GS. Tests with the standard impeller were unsuccessful but with a modified impeller hot and warm start ignition was achieved. It was subsequently agreed to comply with Babcock and Wilcox's suggestion that the circular burners on the Nanticoke GS boilers would be more suitable for plasma arc ignition. It was decided to repeat the demonstration at Nanticoke GS.

The second plasma arc ignition test took place at Nanticoke GS in June 1984. This test was carried out with 35 percent volatile content US coal only but was clearly successful under warm and hot start conditions. However, the plasma arc torch was sited in the centre of a low NO_x burner which had no impeller. It is considered that this design of burner results in unacceptable carbon in ash levels and that a new design - probably incorporating an impeller - should be used. This would not assist a plasma arc ignition program.

One aspect of plasma arc ignition that deserves mention is the ability of a small amount of energy in the form of a plasma flame, to displace a much larger amount of energy in the form of an oil flame for coal ignition in a main burner. The total heat input must be the same of course - for the same boiler warm up. Therefore, the difference in plasma flame to oil flame energy has to be made up with energy from (lower cost) coal.

3.2 Process Description

Since Babcock & Wilcox are considering two different suppliers of plasma arc torch, both will be discussed.

3.2.1 Plasma Energy Corporation (formerly Technology Application Services Corporation)

The original concept for a pulverized coal plasma arc ignitor was to have an ignitor situated below the coal burner but directed into the path of the coal/air mixture leaving the burner. However, once it was determined that the torch diameter could be reduced from 115 mm down to 75 mm Babcock & Wilcox relocated the torch to the centre axis of the main burner. This position was preferred by Babcock & Wilcox as it was felt that more reliable ignition would be obtained, see Figure 2. Other changes were made such as lowering the power supply to the ignitor from 150 kW down to about 100 kW. Development and optimization is still ongoing as briefly discussed below.

Filtered air for ionization in the plasma arc torch is supplied via multiple tangential air ports in the body of the torch. Some of this air is ionized into a plasma flame by an electric arc struck between the electrodes. The rest of the air provides a swirling vortex which is used to stabilize the plasma arc as well as rotate it. During the development of plasma arc torches for coal ignition, it has been determined that the air used for ionization must be moisture free and screened for particulates. It has been found from experience (including the tests at Lakeview GS) that the presence of such contaminants in the arc air supply tend to destabilize the arc, making it less controllable. Plasma Energy Corporation theorize that the plasma temperature is about 7 000°C. The electrodes are water cooled copper tubes. Rotation of the arc is considered to spread the oxidation attack over more of the electrode surface, thus prolonging its life.

Initiation of the arc is by a 15,000 volt dc spark supplied via a capacitative discharge. The resultant arc can then be sustained by 100 kW of power at 750-900 volts dc. A control console supervises the transformation and rectification of the 600 volt ac supply to the dc outputs.

The control console has a microprocessor which monitors and regulates flows of water and air in addition to electricity. Pre-determined interlocks have been set to prevent equipment damage and/or injury to personnel should one of the services fail.

Once the arc is established, coal can be fired. Provided that the air temperature of the coal air mixture is high enough, ignition is quite rapid. The ignitor is kept on until the coal flame is considered stable, then it is retracted. This is the ignitor's application to coal ignition. It can also be used to maintain flame stability when, for example, the coal is excessively wet.

3.2.2 Westinghouse

The Westinghouse plasma arc torch (shown in Figures 2, 3 and 4) is similar in appearance and function to the Plasma Energy Corporation torch. However there are differences. Arc initiation is achieved by a high frequency starter. This device raises the frequency of an alternating current to about 1 MH_Z whereupon the frequency collapses with a resultant high voltage spark. Westinghouse are presently using a silver anode and a copper cathode. The electrodes are assumed to last 320 hours and 150 hours respectively. The use of silver obviously increases the electrode cost but Westinghouse believes that this increase can be justified by the longer electrode life. Some early copper anodes were found to fail in less than 100 hours.

Another difference is the stabilizing of the arc. The Westinghouse torch has an inbuilt coil which when energized, rotates the arc by use of a magnetic field. This action also serves to stabilize the position of the arc.

The Westinghouse torch may or may not be technically superior to the Plasma Energy Corporation torch. At this point in time they are about the same level of development. One possible indicator however, is cost. The Westinghouse torch is more expensive than the Plasma Energy Corporation torch. Babcock & Wilcox started out using Plasma Energy Corporation torches but are now considering switching over to the Westinghouse torch. The sole reason for this change is believed to be the longer electrode life achieved by the Westinghouse torch (presently 200 hours claimed versus 40 for the Plasma Energy Corporation torch). Westinghouse engineers are working to improve their torch electrode life up to 1000 hours or more.

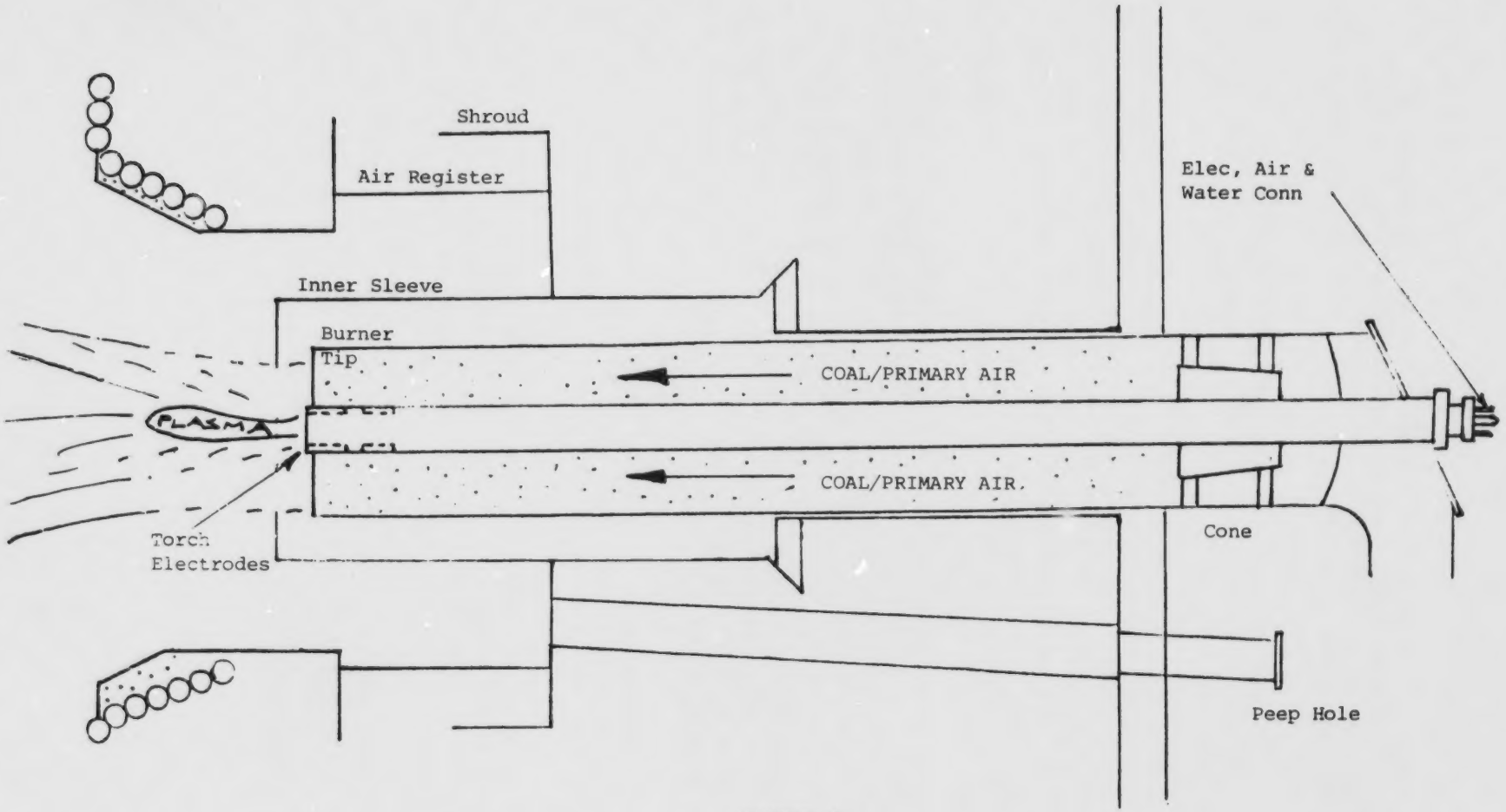

FIGURE 2

PLASMA TORCH IN LANCE ASSEMBLY
IN LOW NOX BURNER AT NANTICOKE UNIT 6
(SHOWING PLASMA FLAME IGNITING COAL)

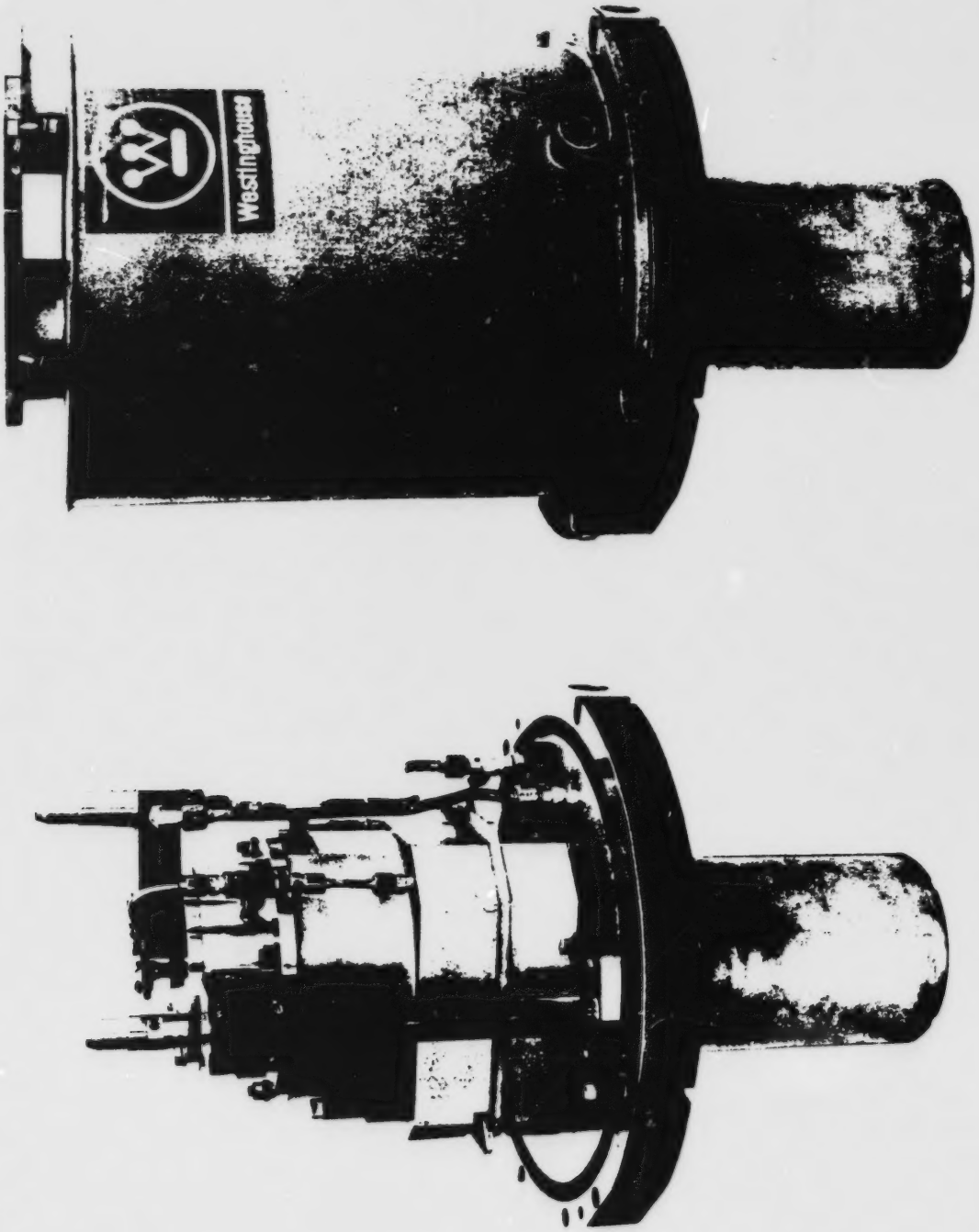

FIGURE 3 WESTINGHOUSE PLASMA TORCH WITH AND WITHOUT PROTECTIVE COVER

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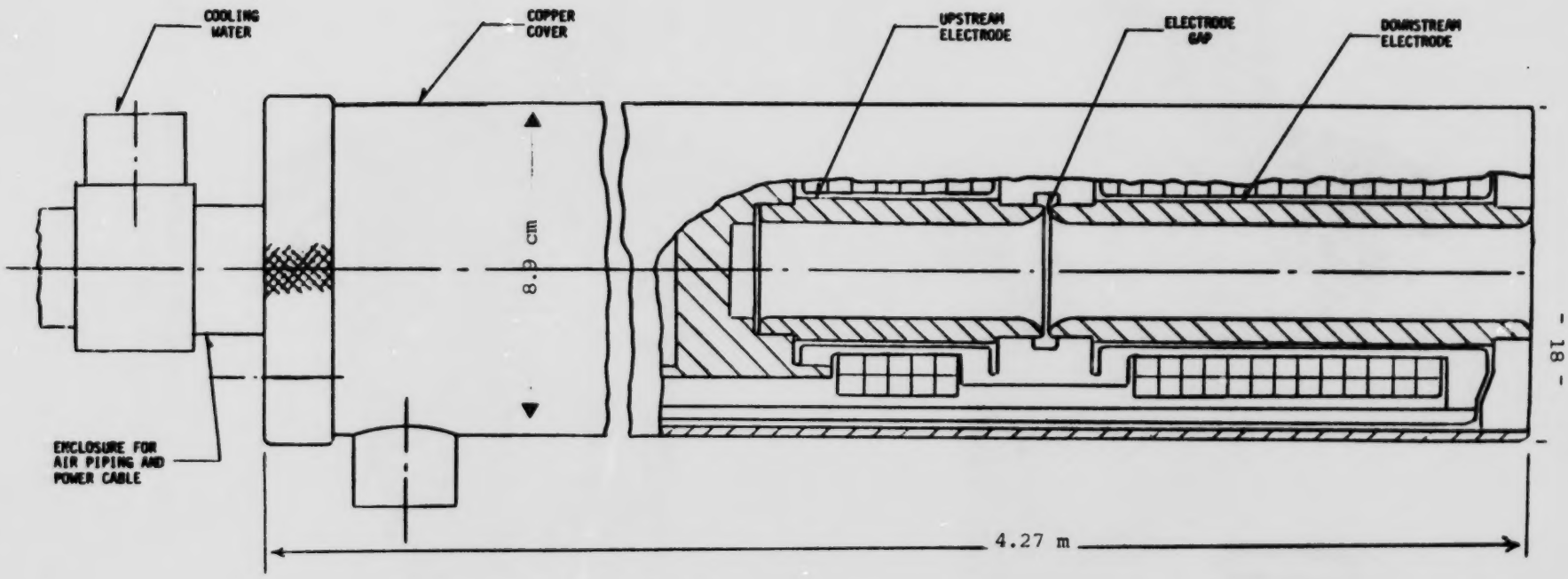

FIGURE 4 CROSS SECTION OF PLASMA LANCE

3.3 List of Advantages and Disadvantages

Advantages of Plasma Arc Ignition System

(a) Plasma arc ignition is apparently capable of warm/hot starts plus flame stability.

(b) Accepting its limited capability, the total operating cost is almost certainly the lowest of any conceivable alternative. While up to 2 MW of auxiliary power is required for the ignitors on a 500 MWe boiler, the power requirement is claimed to be brief, possibly less than 30 minutes. Also, very little maintenance is anticipated for this system - provided that electrodes can in fact last for at least 200 operating hours. Replacement is a relatively high material cost item but should be quite low in labour costs.

(c) It is claimed that the system can also be used for flame stability. This is another item which requires demonstration. However it is conceivable that the plasma arc could assist in the ignition of wet coal which would otherwise fail to ignite.

Disadvantages of Plasma Arc Ignition System

(a) The system cannot be used to bring on a boiler from cold. Ignition oil must be used for the initial warm up.

(b) The capital costs are high enough to make economic justification doubtful. This is very dependent on the need for the system - number of starts - frequency of flame instability periods.

(c) To minimize capital cost the PAIS system may only be fitted to the burners of two pulverizers e.g. 16 burners out of a total of 40 burners at Nanticoke GS. If these pulverizers are inoperable, so is the PAIS.

(d) At this point in time, the PAIS is unproven. Some US utilities have run tests with it and abandoned the idea for unspecified reasons. It is considered that economics are the reason.

3.4 Discussion of Developmental Issues and Problems
Plasma Energy Corporation Igniter

Ionization Gas Supply

The cheapest and most readily available gas for ionization of the electrode arc - the plasma flame - is air. From repeated experience however, it has been demonstrated that the air must be clean of particulates and dry. Moisture in ambient air has shown quite drastic effects on electrodes.

Plasma Energy Corporation have experimented with other gases. From these experiments it is conceivable that nitrogen could be used instead of air. It is readily available and at comparatively low cost. Plasma Energy Corporation believe it could extend electrode life by 50-75 percent. This extension arises from the reduction of oxidation at the electrodes. Another benefit with the use of nitrogen is arc initiation. Much less potential is required to initiate an arc in pure nitrogen than air.

Torch Construction

This is fundamental but as yet still very developmental. However, no real progress is anticipated without considerably more operating experience, e.g., a prolonged test period with a group of plasma arc torches.

Electrodes

Electrodes are literally the hot spot of plasma arc torches for coal ignition. In fact, unless some real development is made here, the whole concept is in jeopardy. As stated in the process description Electrode protection is attempted by various means. None of these are too successful however.

Start Up

At this point in time optimized start up methods have not been achieved for any utility boiler. It is not even known how much air and coal should be sent to the plasma arc modified burner; nor is the minimum air supply temperature known. Some assumptions were made during this study in order to conduct an economic comparison of alternatives.

The present start up times have been established by testing and careful monitoring of metal temperatures. It is likely that the whole start up process with plasma arc would require redefining and thorough demonstration.

Power Supply

At the present stage of development, each torch requires its own power supply. Westinghouse engineers have suggested that using a single power supply with a microsecond switching arrangement could conceivably sustain several plasma arcs simultaneously. If this is possible it would considerably lower the capital cost.

General

Unit 1 at the future Intermountain GS (Utah) is to have 24 plasma arc igniters as well as an oil ignition system. This is regarded as an experiment however, and the Unit 2 ignition system will be determined after operating experience on Unit 1.

4.0 NATURAL GAS

4.1 Introduction

Natural gas is the most obvious alternative to No. 2 oil for ignition and warm up of coal fired boilers. It is readily combustible in all boilerhouse situations and at the present time costs about 65 percent of the price of No. 2 oil. Historically, natural gas was always lower in price than oil, although even oil at 2 or 3 cents/litre was very cheap. It appears that oil ignition was originally installed for security of supply. Also there may have been some fears about the potential hazard of having natural gas in the station.

There are slight differences in the combustion of natural gas from No. 2 oil. The flame is less luminous and different flame scanners are required to detect that the flame is actually present. Also there is a little less radiant heat transmitted to the waterwalls of the furnace. However, these aspects are marginal and have no significant bearing on the ability of natural gas to replace No. 2 oil as an ignition fuel.

As stated in the general introduction to the report, oil reserves are becoming more evidently finite. This is quite different from the natural gas situation especially in Canada. Even with a growing demand, there is no shortages in natural gas envisioned for at least 43 years (National Energy Board statement - 1983 gas export hearings) and even this value is considered to be a very conservative estimate.

4.2 Conversion Description

Unlike the other alternatives, there is no process description required. The natural gas is simply supplied to the boilers via a pipe system and fired when required.

The natural gas ignition system would have the same heat input capability as the No. 2 oil system. It is also assumed that OM&A costs for a natural gas ignition system would be 85 percent of that of the existing oil system. This is due to the fact that no (Ontario Hydro) pumping is involved. Also oil, although not particularly erosive, is more so than natural gas.

Natural gas would arrive at the generating station via the gas company's metering station. From this point the gas would be transported through a large header which would have take offs for each boiler. At Nanticoke GS the header would be 600 mm diameter and the individual boiler lines 250 mm.

Flow (measuring) and pressure (controlling) transmitters would be installed in each individual boiler line. The pressure transmitter would control the gas flow by means of a pressure reducing valve.

Each of the 250 mm lines would have manual shut off ball valve and and an ignition trip valve. Also on the individual burner lines there would be double shut off valves (plug type) with a vent valve in between. The vent valves open when the shut off valves close. Any gas vented is piped to atmosphere.

It is assumed that if a gas piping system is installed, then the existing oil system would be removed.

As shown in the capital costs Table 7.3, a considerable part of the cost is instrumentation and control. There are two main reasons for this. New flame scanners are required as gas flames have a different spectrum from oil flames. Also control logic for burning natural gas is different from the logic used for burning oil.

4.3 List of Advantages and Disadvantages

Advantages of Natural Gas

(a) Demonstrated capability.

(b) Natural gas can be used to replace oil for all ignition sequences and flame stabilization. Thus, this alternative - alone - is capable of complete elimination of oil.

(c) Using natural gas for ignition is the most environmentally acceptable alternative. There would be no particulate emissions and no significant acid gas emissions. Also the precipitators could be switched on just prior to coal firing.

Disadvantages of Natural Gas

(a) The generating station is more dependent on an external agency during start up periods, unless large gas storage (which is undesirable from a capital and operating point of view) exists at the station. While this is probably not a problem today, there is no certainty that this would be the case in the future.

(b) Natural gas by virtue of its permeability has to be regarded as a more hazardous fuel than even ignition oil.

(c) The combustion of natural gas produces more moisture than oil or coal for the same heat output. This could increase corrosion in the precipitator and latter passageways of the boiler.

5.0 COMBUSTION ENGINEERING SYSTEM

5.1 Introduction

Combustion Engineering have designed a system for coal fired boiler ignition which uses stored pulverized coal as the means of boiler warm up. The original concept called for a high energy electrical spark to ignite the coal when it was supplied to the boiler. This system is in use at TVAs Bull Run GS near Knoxville, Tennessee (see Appendix III).

However, Combustion Engineering have had a change in philosophy. The installation offered to Ontario Hydro is no longer a "direct coal ignition" system but rather is a "coal warm up" system. Two major changes to the Bull Run GS system have been made for the proposal to Ontario Hydro. Firstly, the electrical spark iginition has been omitted. This duty has been given over to small ignition oil torches. Secondly, whereas at Bull Run GS the coal igniter guns directly replaced the existing oil igniters in duty and actual physical location, the coal guns would have a new location at Lambton. Actually as shown in Figure 5 the new coal guns would be placed in spaces left for a boiler coal to oil conversion. With this arrangement ignition oil is still required to ignite both the new coal burners and the existing main burners.

The reasons for the change in philosophy are essentially based on three factors. By using ignition oil instead of an electrical spark, coal ignition is guaranteed. Also, the coal particles can be of normal pulverized size, not ultrafine as preferred for the electric spark alternative. Finally, using oil is simpler with present day technology.

5.2 Process Description

The following process description is for an ignition conversion as applied to two Lambton generating units. Two systems would therefore be required for four generating units. Only Lambton GS is considered for this system at the present time. Combustion Engineering felt that much more study would be required on their part to submit a quotation for the Babcock and Wilcox boilers at Nanticoke GS.

As shown in Figure 5, an additional pulverizer would be located under the existing coal bunkers and connected to the bunkers so that it could receive raw coal as required. While the unit is on load, this additional pulverizer can be supplied with hot gas so that coal can be pulverized and dried in a reasonably inert atmosphere. The pulverized coal is transported by means of the hot flue gas to a cyclone separator where the coal is centrifuged out and dropped into a triple compartment storage bin (three compartments, each of 127 000 kg capacity). The remaining flue gas is power vented by a fan into the boiler windbox or, if required, recirculated to the pulverizer. A carbon dioxide inerting system has been assumed for the pulverized coal storage bins.

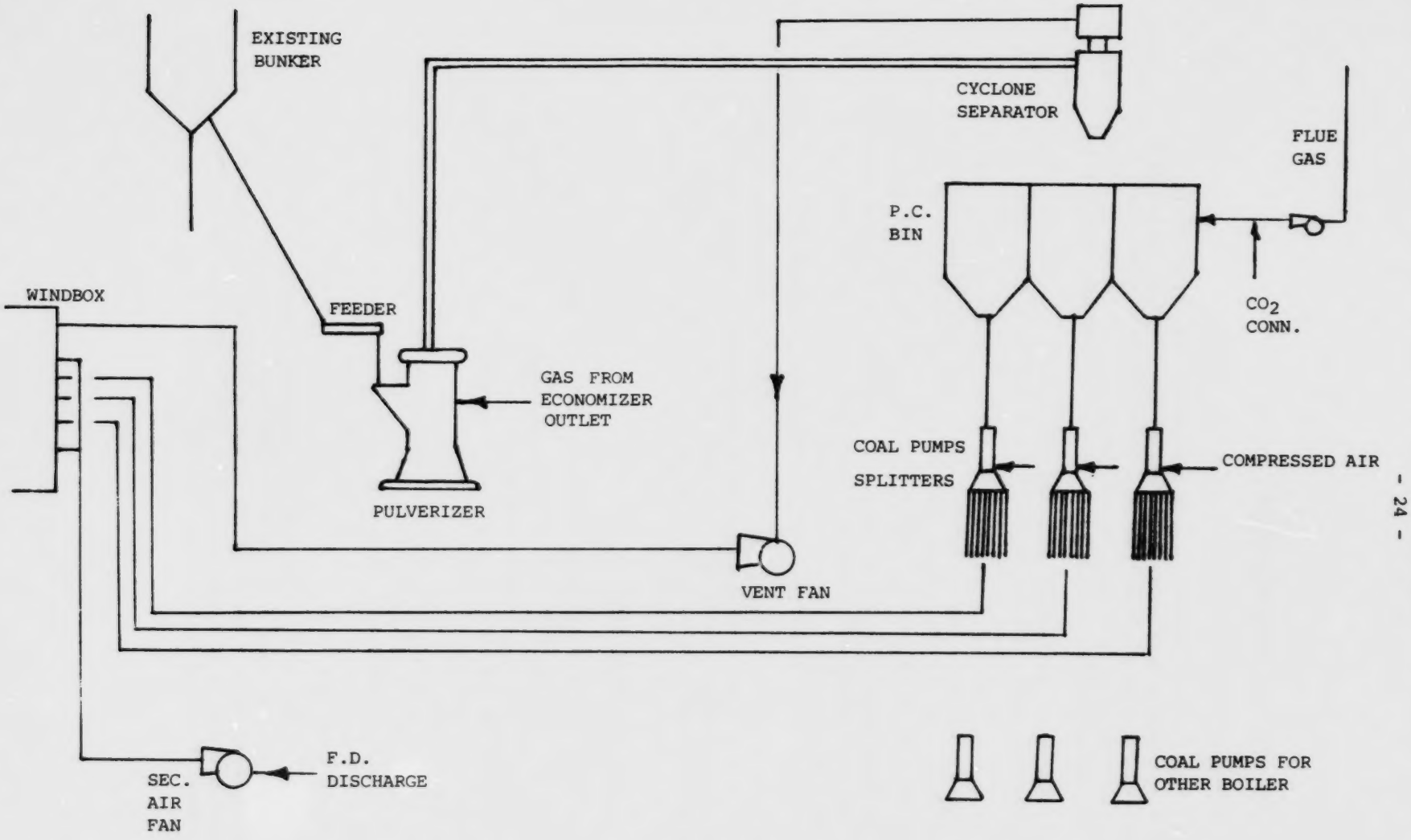

FIGURE 5
COMBUSTION ENGINEERING SYSTEM

Pulverized coal could be produced and stored using the existing pulverizers at Lambton GS or any other station. However, this would entail considerable modifications to one or more pulverizers (for a reliable supply). Also producing ignition coal with a main pulverizer could curtail the unit's generating capacity during peak periods. This type of drawback could offset the gains of having a coal ignition system.

Stored coal is drawn off the bin when required for ignition or flame stabilization purposes, by a gravimetric feeder system. The gravimetric feeders are used to measure and control the quantities of coal passed to a coal pump.

Coal pumps in conjunction with compressed air pass the coal via flow splitters through eight separate pipes to the windbox burners. The pumps are reducing volume screw devices which effectively seal against backflow of the compressed air which is injected just at the pump outlet. At Bull Run GS, the coal/air mixture is at a pressure of about 340 kPa and is delivered to the burners at a velocity of about 20 meters/second. This coal air mixture is really dense phase transportation of coal. The air is about 97 percent of the stoichiometric requirements for coal combustion. Secondary air fans are used to supply the necessary excess air for successful combustion.

Figure 6 shows the Lambton coal burner and side oil igniter arrangement as it exists today. There are six rows of combined coal and side oil igniters in each of the eight furnace corners. Figure 7 shows the windbox modifications that would be made for the installation of coal warm up guns. The new guns would go in a space left for oil guns. This space is a standard feature of the Combustion Engineering boilers of that period (pre 1973). A utility could rapidly convert the boiler from coal to oil firing if required.

Coal passing through the new ignition burners would be ignited by existing but slightly relocated side oil igniters at Lambton GS. The igniter tips however would be reduced to pass 15 mL/sec of oil instead of 52.9 mL/sec as at present. Combustion Engineering believe that a five minute period only, would be required to achieve a stable flame on coal. Thus, the rest of the boiler warm up should be using coal. A new set of sensitive fibre optic flame scanners are required to ensure that a stable coal flame has been achieved before switching off the side oil ignitors. Exactly how much oil would be required can only be an educated guess. The assumptions issued for this study are detailed in Appendix II.

Obviously different coals would have different degrees of success with this system. Combustion Engineering have stated that anthracite type coals would not ignite satisfactorily, if at all, with this arrangement. No great difficulty is expected with US eastern bituminous coal. However, reactivity tests are stated to be worthwhile. Combustion Engineering believe that the system could work with lignite although it would certainly be a less promising fuel than high volatile bituminous coal.

Note: Lambton GS does not receive any Western Canadian coal and there are no longer any plans to do so.

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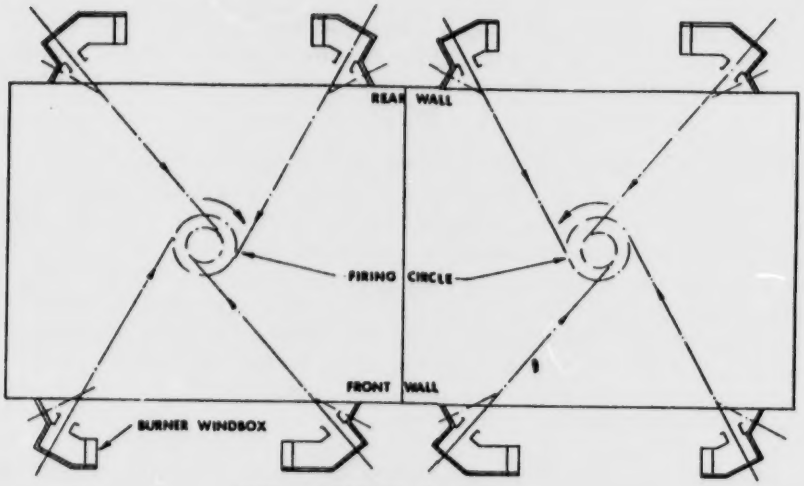
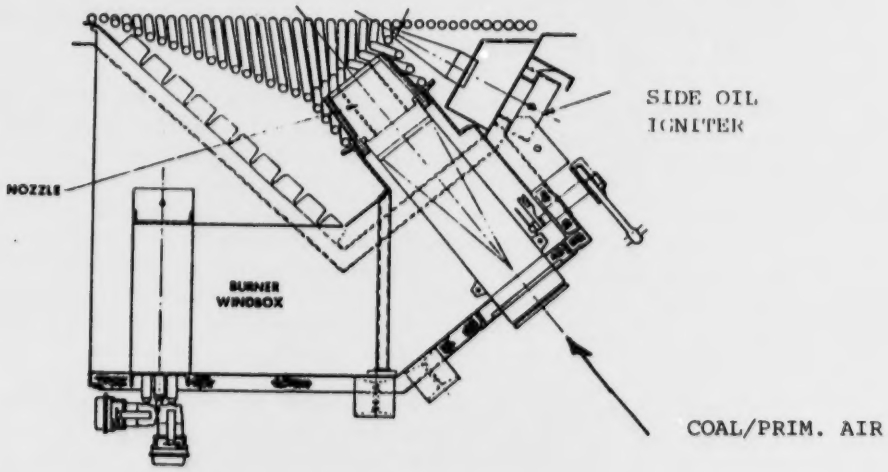


BURNER ARRANGEMENT PLAN



PLAN

(ONE OF SIX ROWS OF BURNERS)

FIGURE 6

COMBUSTION ENGINEERING
BURNER ARRANGEMENT AT LAMBTON GS

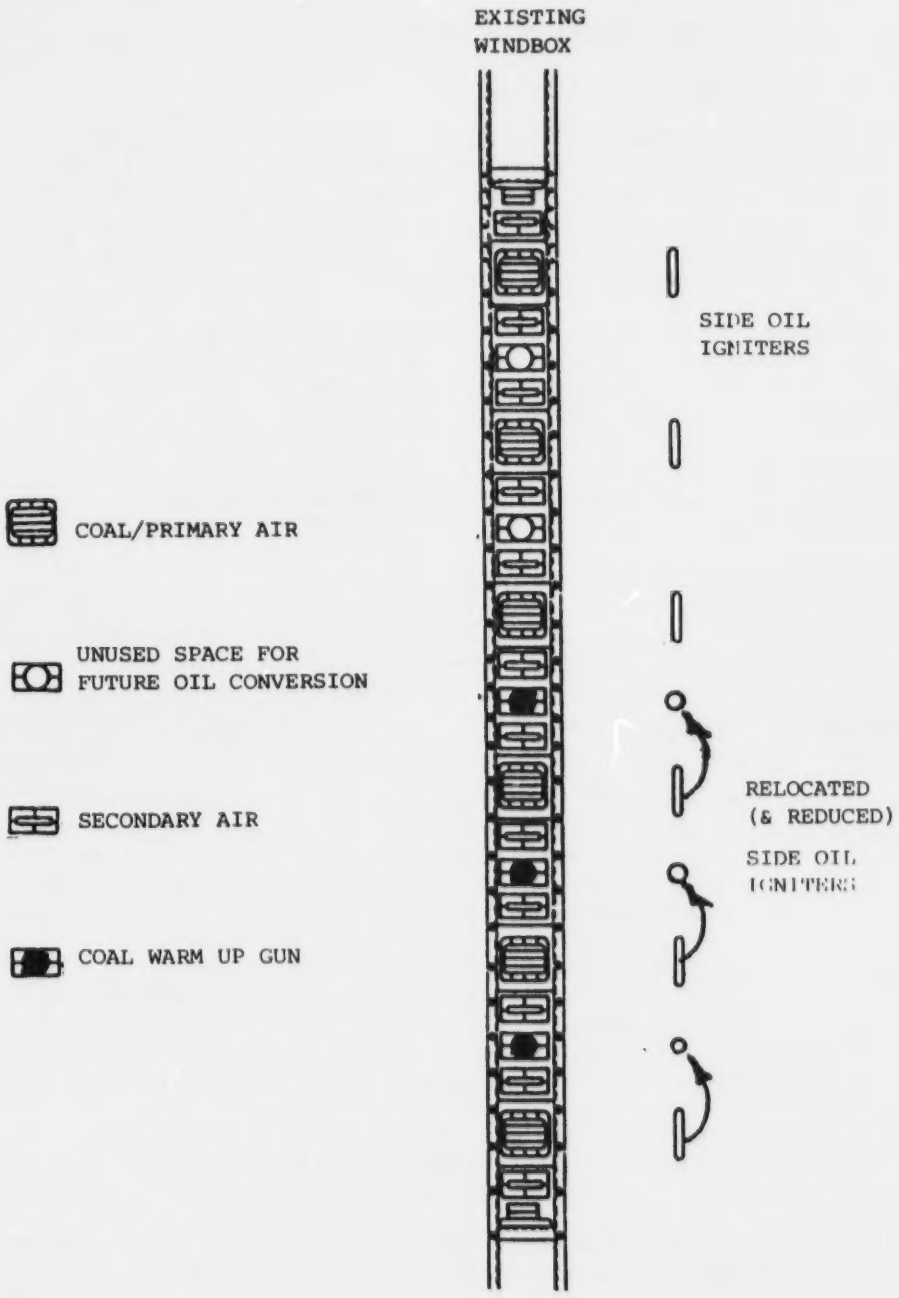


FIGURE 7

COMBUSTION ENGINEERING

MODIFICATIONS TO LAMBTON GS WINDBOX

5.3 List of Advantages and Disadvantages

Advantages of Combustion Engineering System

(a) The CE system is designed to be able to bring a coal fired boiler on load from any starting condition hot or cold. However this must be qualified. To date (August 1983) only hot start recovery has been proven on the Tennessee Bull Run GS. It is conceivable that much more side oil ignition woud be required at Lambton GS than CE claim.

(b) In addition to start ups, the CE system can be used to rapidly recover load lost due to wet coal or pulverizer problems etc. This is in effect, having an additional pulverizer between two generating units with a source of dry coal.

(c) Complete elimination of ignition oil may be possible with the use of electrical spark igniters. However, the CE system offered to Ontario Hydro does retain partial oil firing.

Disadvantages of Combustion Engineering

(a) The system is very capital intensive. Some economies are possible, but considerations such as using a unit pulverizer instead of a new one for supplying pulverized coal for storage, detract too much from the merits of the system for the economic benefits gained.

(b) Handling and storing of pulverized coal is hazardous. Storing pulverized coal was carried out a few decades ago and abandoned due to the practical difficulties. The main dangers are in transporting the pulverized coal, particularly where air ingress is possible or where coal leakage to the ambient can take place.

(c) The system as applied is fairly complex. It is conceivable that the system would be at least partly down on some occasions when it was required. From the coal pumps on there is parallelling of equipment. The size and complexity of the system almost certainly necessitates high operating and maintenance costs.

(d) This system could have the greatest negative environmental impact due to the high quantity of solid fuel being fired into a cold boiler.

(e) It has been assumed for this study that the system could only be used for 50 percent of all flame stabilization periods.

5.4 Discussions of Developmental Issues and Problems

Dense phase transport is used to transport the coal air mixture to the ignition burners. This practice in itself is still developmental. In the Combustion Engineering system this dense phase transport is further aggravated by splitting the coal air mixture from each coal pump into eight separate small bore (25.4 mm) pipes. To achieve this on a regular day-to-day basis will either demand a lot of maintenance or some very clever design development.

The coal pumps frequently require new internals (volume reducing screws). CE are experimenting with various materials. However as above, either a lot of maintenance will have to be accepted or some development will be required. It is conceivable that CE may consider other types of coal transport equipment than the coal pumps used at Bull Run GS, Tennessee and proposed at Lambton GS.

Coal reactivity is regarded as a potential problem by CE if a customer prefers electrical ignition over oil. CE obviously believes that the use of some oil ignition removes much, if not all of the difficulty of igniting coal. CE also state that size of coal grind becomes much less important when using oil. There is no doubt that the use of oil would be easier for ignition. However there is no demonstration available. It is possible that more oil is required than anticipated. Also it is possible that the ignition sequence may not be too environmentally acceptable.

Nobody, including Combustion Engineering can be sure that the proposed system could be used in a cold start situation. It is conceivable that use of the side oil igniters would have to be continuous for early start up. Worse still it is conceivable that use of the side oil igniters achieve complete ignition of the coal supply.

6.0 STEINMULLER SYSTEM

6.1 Introduction

Steinmuller is a West German engineering company who design and manufacture boiler firing systems. The Steinmuller approach to direct coal ignition is similar in many ways to the Combustion Engineering system described in Section 5 of this report. There are also many differences however as described below.

There are two commercial applications of the Steinmuller ignition system in operation - a 500 MW unit in South Africa and a 150 MW unit in West Germany.

Steinmuller are the only company who have submitted comprehensive proposals for Lambton GS and Nanticoke GS. They declined to bid on the smaller Thunder Bay GS however. Unfortunately their proposal for Lambton GS has not been well received. The Boiler Group of Power Equipment Department would not accept the Steinmuller initial proposal as major boiler surgery would be required to install the Steinmuller pulverized coal igniters. A modified proposal to utilize multiple small igniter burners, five instead of one in each corner, was not too well received either. This latter approach was passed by Ontario Hydro to Combustion Engineering (who supplied the Lambton boilers), for comments. Combustion Engineering declined to comment officially but implied verbally that they could not see any economic justification for such a modification. With this situation the Steinmuller proposal for Lambton GS had to be eliminated from further consideration.

For the record, the capital cost estimate for the initial Steinmuller proposal at Lambton GS was 80 percent of that for Nanticoke GS per boiler, and was 150 percent for the modified five igniters/corner case. The reasons for the economy at the Lambton GS versus Nanticoke GS was the lower number of igniters involved plus the fact that Lambton GS has spare pulverizer capacity whereas Nanticoke GS has not. Steinmuller proposed tap offs from the existing pulverizer coal/air pipes for ignition fuel at Lambton GS but new pulverizers at Nanticoke GS.

The process decribed below is a modification of Steinmuller's proposal(s) for Nanticoke GS. Whereas the Lambton GS proposal was ultimately completely rejected, only a limited version of one of the Steinmuller proposals was considered acceptable at Nanticoke GS, and even this scheme gives serious doubts as to a viable installation. The accepted scheme calls for siting a maximum of 16 Steinmuller ignition burners on the wall of each Nanticoke GS boiler. By placing the ignition burners in this way, they can no longer be described as igniters but simply as warm up guns. Ignition oil would still be required to light main coal burner flames and to provide stability when coming off load etc. Figure 8 shows the present coal and oil burner arrangements. Steinmuller are familiar with this problem and have stated that oil burners should only be on for

a maximum of 30 minutes when bringing on main coal burners. Thus although the Steinmuller system can considerably reduce ignition oil requirements at Nanticoke GS, there will still be a substantial oil burn. Estimates for this are shown in Appendix II.

Figure 8 shows the existing burner arrangement in all Nanticoke boilers except Unit 6.

6.2 Process Description

For expedience, the Steinmuller sytem is described under (a) system and (b) ignition burner.

(a) System

As illustrated in Figure 9, a central processing facility is proposed for each group of four generating units at Nantiocke GS. Each facility is assumed to have a separate raw coal bunker.

Coal from the bunker is fed to a tube mill where it is ground to about 80 percent smaller than 50 microns at a rate of 5.6 kg/sec. This grinding is carried out with a primary gas supply at 210°C which is supplied by an oil fired hot gas producer. In addition to supplying an inert medium to transport the pulverized coal, the hot gas dries the coal to prevent future bridging and plugging, also to enhance its combustion characteristics. The 0.5 GJ/hr hot gas producer is the first piece of equipment brought into service as it is also used to warm up the circuit prior to grinding etc.

Coal is transported from the tube mill to a filter bag arrangement for collection in a hopper. The actual transport is effected by a carrier fan which draws the coal/gas mixture from the tube mill classifier up to the filter bag. This coal/gas mixture contains approximately 20 tonnes/hour of coal in a 600 grams/normal metre^3 concentration in flue gas. The coal is cycloned out into a collecting hopper and the carrier fan exhausts gas with a maximum of 100 milligrams/normal metre^3 of coal to atmosphere.

At the bottom of the hopper, coal is removed out by a screw feeder and gravity fed via a rotary seal air lock to the pulverized coal storage bin. The bin has a nominal capacity of 300 m^3 or 180 tonnes of coal and is 6 metres in diameter and 16 metres high. There are four storage bins, one per boiler. Only one can be fed at any one time.

The coal is then removed from the bottom of the storage bin by a screw feeder and gravity to two lock hoppers. From the lock hoppers onwards, the operation becomes a pressurized feeding system. Each of the 2 metre^3 lock hoppers receives coal on (firing control) demand from the pulverized coal storage bin provided that there is coal above the minimum level. Coal falls into the lock hoppers until a high level trip shuts off the filling valves. There are two valves in each filling line and they close in a slow sequence thus ensuring a good seal. The lock hoppers are then pressurized with compressed air which pushes the coal

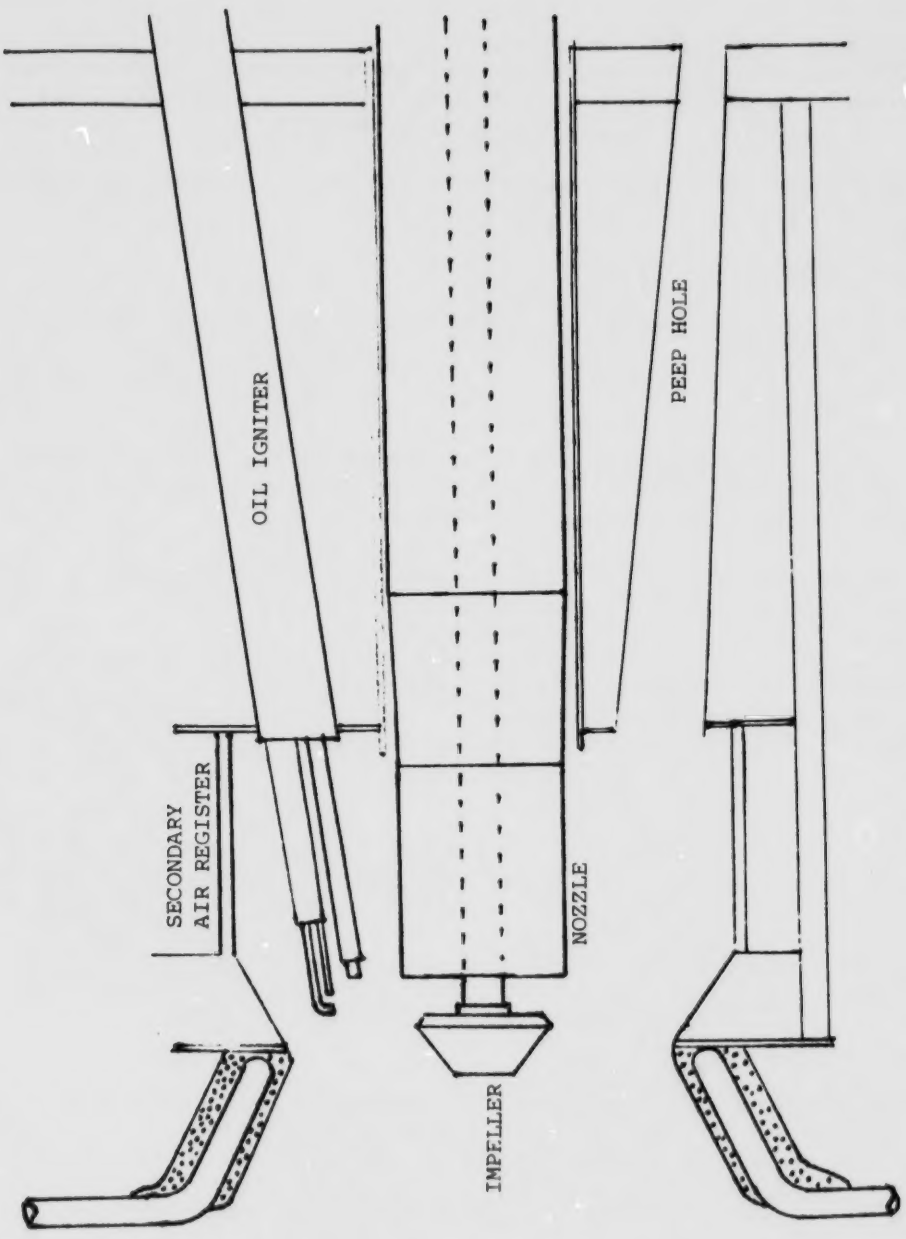


FIGURE 8
SKETCH OF NANTICOKE GS CIRCULAR COAL
BURNER AND OIL IGNITER

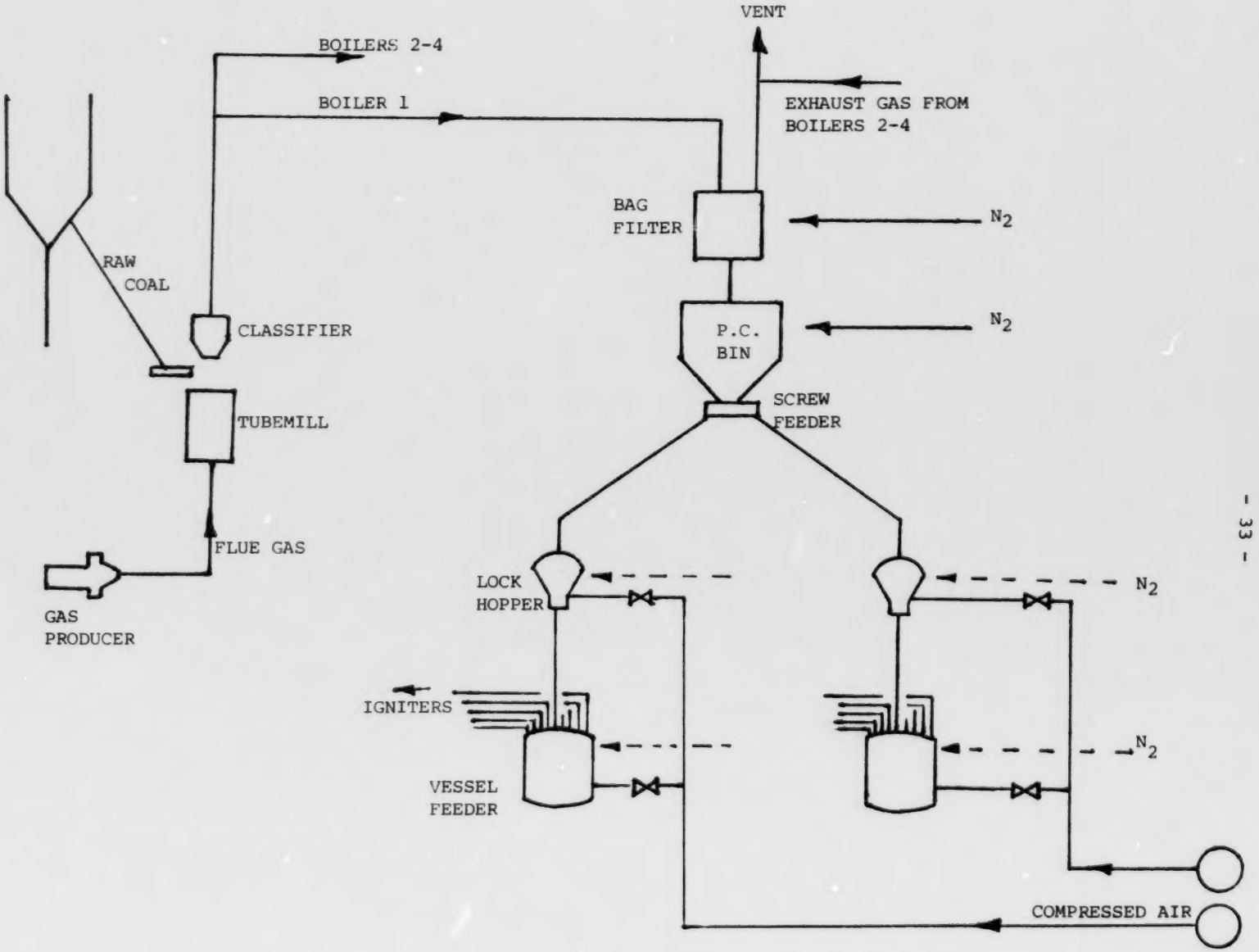


FIGURE 9
STEINMULLER SYSTEM FOR 4 BOILERS AT NANTICOKE GS

through non return valves to two vessel feeders. When the coal reaches a minimum level in the lock hoppers, they are de-pressurized ready for another filling cycle. Presumably the air is vented via a filter bag to a vent line.

The vessel feeders have a 5 metre^3 capacity and like the lock hoppers are normally controlled by high and low level switches. For the Nanticoke GS case each vessel feeder would have eight outlets for supplying coal to the Steinmuller burners. The actual flow of coal is by air ejection and is controlled by air pressure. To assist smooth flow, there are horizontal agitators at all the extraction points. The compressed air is supplied by 2 x 100 percent centrifugal air compressors which are cross-connected for redundancy. Each individual extraction point can be closed automatically. In this event the coal is shut off but air supply continued to clear the line of coal. In the case of a boiler or unit trip all ejectors are closed immediately.

It is well known that any carbonaceous dust can form an explosive atmosphere in ambient air. Pulverized coal is no exception although fire is probably a greater hazard. To minimize these risks, air is removed from all internal process components where there is pulverized coal. The main areas of concern are the filter bag and the pulverized storage bins. When the generating unit is operating normally, this is achieved by supplying flue gas. Thus flue gas inerts the pulverizer and the line to the filter bag. The filter bag also has nitrogen injection which is implemented whenever one of the sensors (oxygen analyzers, thermocouples) dictate a requirement. Inerting of the lock hopper and vessel feeder are not normal practice - these are robust components and are in effect pressure vessels. However emergency nitrogen lines are provided for these vessels.

Finally, corrosion protection from acid dew point corrosion is provided by electrical trace heating in the bag filter and collecting hopper also the pulverized coal storage bin.

(b) Steinmuller Ignition Burner

Figure 10 shows the Steinmuller pulverized coal ignition burner. It was designed as a smaller version of Steinmuller's own circular pulverized coal burner. Further, the ignition burner was originally designed to be mounted co-axially or concentrically in the main burner. Mounting the burner elsewhere in the boiler as would be required at Nanticoke GS is a compromise. Ignition oil burners are still required, possibly for all ignition phases other than warm up. Also, this latter type of mounting leads to substantial retrofit costs.

Steinmuller claim that the igniter can be used for all ignition sequences including cold starts. However, upon investigation it was discovered that a cold start in the German boiler fitted with Steinmuller igniters is not a severe test as the boiler is primed with 80°C feedwater.

The ignition sequence calls for an easily ignitable fuel to be passed down the centre orifice and electrically spark ignited. Steinmuller say light oil or gas can be used but they offered propane ignition to Ontario

Hydro even though they were aware that light oil was available. Gas is preferred as it seems that a flame scanner can differentiate between a coal flame and gas flame but not so well between a coal flame and oil flame.

Steinmuller claim that the igniter burner design incorporates features which enhance the burners own combustion capability. The deflection at the widened head to eliminate the possibility of coal stratification, and an adjustable swirler which brings about a backflow of hot combustion products to the root of the flame. There is also an inner recirculation which transports heat back to the recirculation zone, and a reduction of heat required for combustion air due to the richness of the fuel/air mixture in the combustion zone. It is difficult to comment with authority on these claims. Demonstration is perhaps the answer here.

The gas igniter is on for two periods or phases. A high heat input phase to warm the ignition zone and start off coal combustion, followed by a lower heat input phase which is required merely to maintain stable coal ignition. In the case of the 8 MW (th) coal igniters for Nanticoke GS, the output from the two gas fired phases are probably in the order of 0.5 MW (th) and 0.02 MW (th) respectively. The actual time period that the gas would be required remains unspecified for the present and would probably have to be determined at Nanticoke GS.

However, based on actual operating experience in South Africa and West Germany, the ignition burners would be brought on sequentially - probably in pairs. The gas would be fired first, at the high flow rate, and then the stored pulverized coal would be fired. No significant delay occurs from zero coal to 100 percent coal. The high rate of gas remains on until the first main pulverizer can be brought on. This is when air from the boiler is warm enough to be recirculated to the pulverizer to carry out mill preheating and give a coal/air mixture temperature in the burner pipe of 80°C. Once the pulverized coal from the main burners is satisfactorily ignited the gas flow rate in the ignition burners is reduced to the minimum. As stated earlier however the oil igniters for each respective main coal burner will be required for up to 30 minutes at each burner.

Due to the fineness of the pulverized coal used for the ignition burner, it is claimed that cold air can be used for secondary and primary air even during cold starts. However any heat that is available aids combustion and cuts down the quantity of support gas required. Figure 11 is a series of graphs plotted by Steinmuller which shows the ignitability of various sizes of pulverized coal versus combustion air temperature. From this it is very apparent why fine grinding is required for the ignition burner.

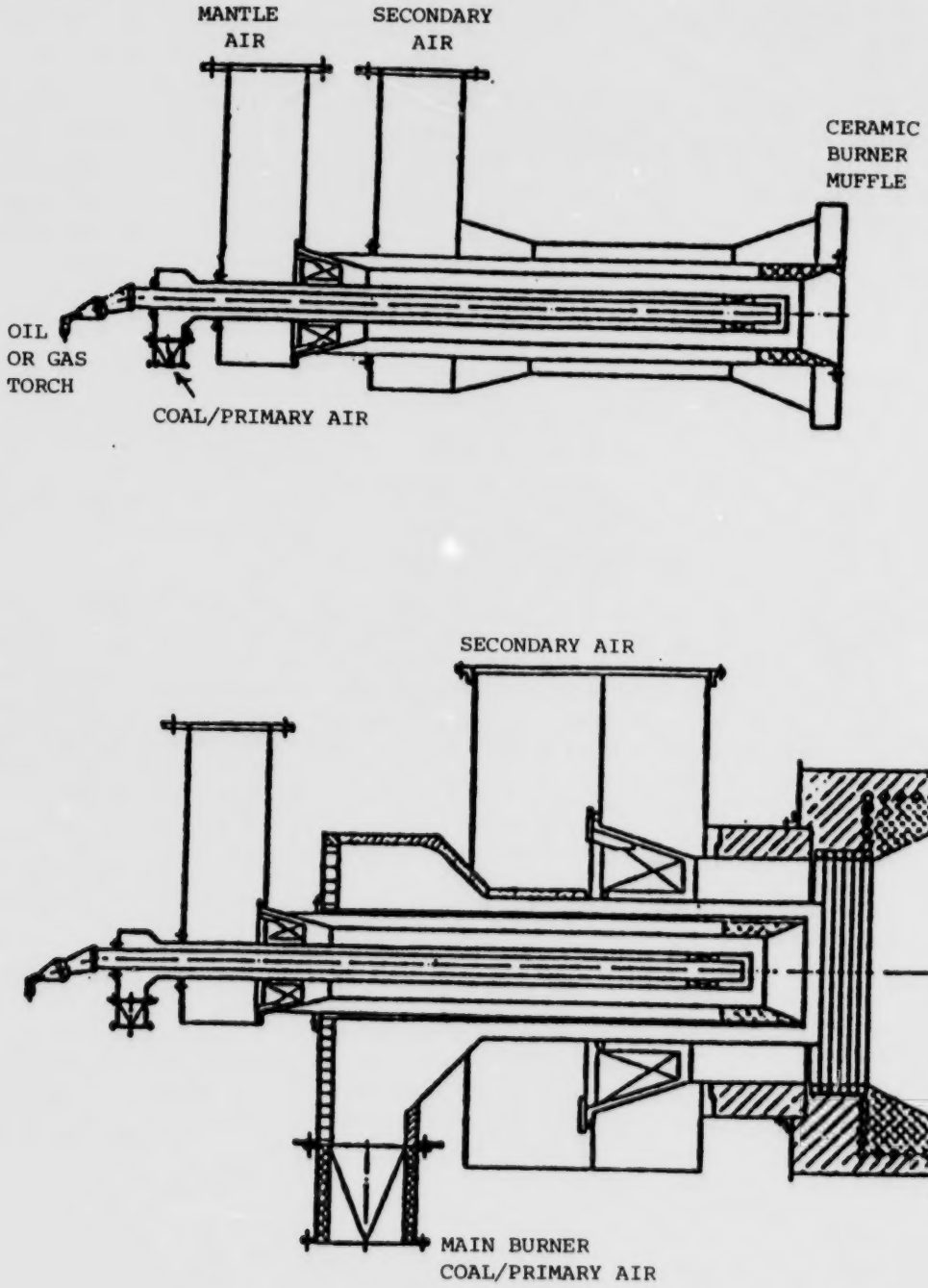


FIGURE 10
STEINMULLER P.F. COAL IGNITER
TOP - INDEPENDENTLY MOUNTED
BOTTOM - CONCENTRICALLY MOUNTED IN MAIN (STEINMULLER) BURNER

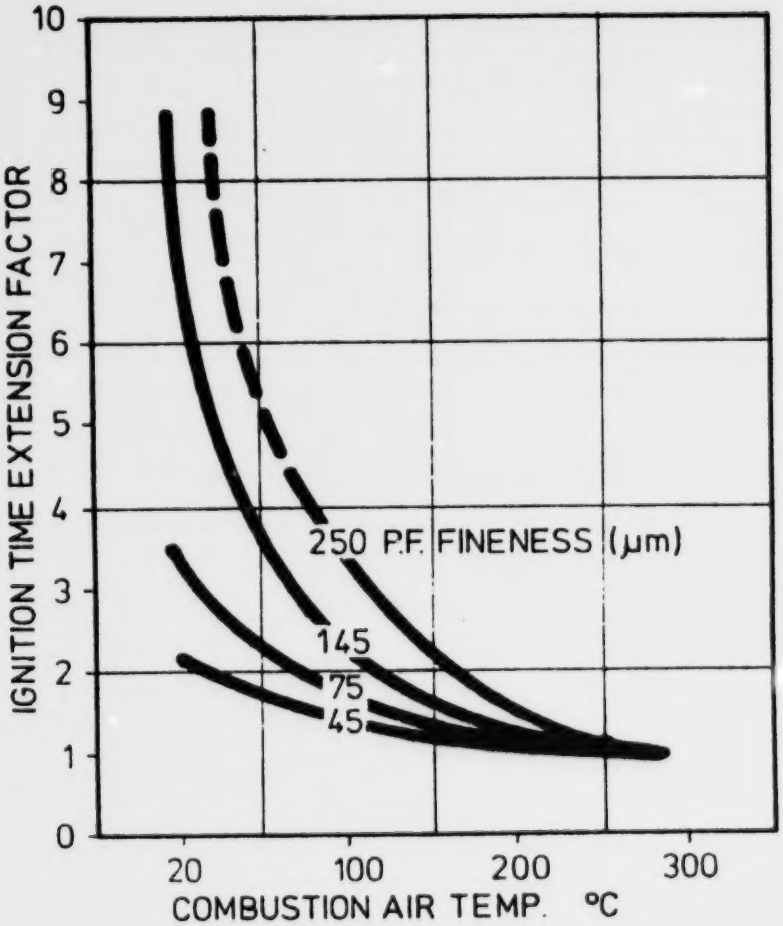


FIGURE 11

EFFECT OF AIR PRE-HEAT ON IGNITION

TIME OF P.F. PARTICLES

(courtesy Steinmuller)

6.3 List of Advantages and Disadvantages

Advantages of Steinmuller System

(a) The Steinmuller system as designed is universally capable of all types of starts and flame stability. However due to the retrofit aspects of the system as applied to Nanticoke GS, some oil ignition is still required for all occasions. It has been assumed for this study that 50 percent of all flame stability requirements are still met by ignition oil firing. (This does not include the start ups.)

(b) In addition to boiler warm up, the Steinmuller system could be used to maintain boiler output in the event of a main pulverizer failure.

Disadvantages of Steinmuller System

(a) The system is very capital intensive.

(b) The Steinmuller system is simply not suitable for retrofit applications (other than boilers which already have Steinmuller main burners).

(c) Hazards of handling and storing pulverized coal.

(d) There would be high particulate emissions during start up.

7.0 ECONOMIC COMPARISON

This economic comparison is based on 20 year life time costs of installing and operating the alternative ignition systems in two generating stations versus leaving them on the existing ignition oil. Wherever possible actual costs and values have been used. Some assumptions have been necessary due to the developmental aspects of the system; these are listed in the respective subsections.

Table 7.1 is the economic summary of the study results. Two points must be made. The total lifetime costs are based on the forecast capital and operating costs for each respective year, present worthed back to the starting year using Ontario Hydro discount tables. In some instances where annual operating costs are very low this has the effect of giving a total lifetime cost lower than the present capital cost.

The second aspect is the payback periods. Those shown in the table are based from the start of capital payments for the respective alternatives, until the crossover point is reached between the cumulative present worth of operating costs of the existing oil system and that of the alternative. Therefore, alternatives with longer construction periods will have longer payback periods for this reason alone. Design and construction periods assumed for each alternative are as follows:

Alternative	Design and Construction Period Years
Coal Oil Mixture	2
Plasma Arc	1
Natural Gas	2
Direct Coal Ignition	3

TABLE 7.1

ECONOMIC SUMMARY

	LAMBTON GS				NANTICOKE GS			
	High Ignition		Low Ignition		High Ignition		Low Ignition	
	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years
	x 10^3		x 10^3		x 10^3		x 10^3	
Existing Oil								
Capital	0	N/A	0	N/A	0	N/A	0	N/A
Fuel (annual)	1,526		468		5,820		3,050	
OM&A (annual	36		25		107		86	
TOTAL LIFETIME PW	20,878		6,522		97,894		51,611	
Coal Oil Mixture								
Capital	10,744	20+	10,744	20+	15,920	12	15,920	21
Fuel (annual)	1,132		352		4,306		2,258	
OM&A (annual)	71		50		214		171	
TOTAL LIFETIME PW	23,268		13,265		80,490		48,591	
Plasma Arc - Total								
Capital	45,621	20+	45,621	20+	75,938	24+	75,938	24+
Fuel (annual)	852		301		3,431		1,885	
OM&A (annual)	33		23		100		80	
TOTAL LIFETIME PW	45,557		39,375		109,730		87,669	
Plasma Arc - Partial								
Capital	17,703	20+	17,703	20+	33,703	18	33,703	24+
Fuel (annual)	1,025		335		4,057		2,154	
OM&A (annual)	34		24		104		83	
TOTAL LIFETIME PW	26,205		17,790		89,226		60,115	

Cont over

ECONOMIC SUMMARY (CONT'D)

	LAMBTON GS				NANTICOKE GS			
	High Ignition		Low Ignition		High Ignition		Low Ignition	
	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years	$1984	Payback Years
	x 10^3		x 10^3		x 10^3		x 10^3	
Natural Gas								
Capital	10,721	18	10,721	20+	15,486	9	15,486	14
Fuel (annual)	1,014		309		3,882		2,034	
OM&A (annual)	31		21		91		73	
TOTAL LIFETIME PW	20,108		11,946		67,083		40,934	
Direct Coal Ignition			CE System				Steinmuller System	
Capital	33,257	20+	33,257	20+	57,607	23	57,607	24+
Fuel (annual)	831		233		3,435		1,786	
OM&A (annual)	166		116		288		230	
TOTAL LIFETIME PW	35,272		27,689		92,244		68,585	

7.1 Capital Costs

For the most part capital costs of alternative ignition systems are based on manufacturers budget quotations. However, there is considerable Ontario Hydro input in computing total system costs. All related indirect costs - overheads, interest during construction, etc. were calculated using Ontario Hydro's standard procedures.

In two cases - the plasma arc and natural gas alternatives where budget costs were obtained for only Nanticoke GS, capital costs have been estimated for Lambton GS. It is considered that these estimates are well within normal study accuracy limits. As demonstrated later, it would require a very large deviation in estimate of capital cost to have any significant effect on the total lifetime cost of an alternative.

7.1.1 Capital Cost Estimate for COM

In compiling the capital cost estimates for COM systems at Lambton GS and Nanticoke GS, the following assumptions have been made:

(a) All oil burners replaced by new COM burners (which are still capable of burning No. 2 oil only).

(b) Complete redundancy (100 percent) of all electrical/mechanical equipment for manufacturing and transporting COM. The main agitator in the storage tank is an exception to this; however there would be a spare electrical motor and gearbox speed reducer.

(c) No Instrumentation and Control equipment costs arise in the boiler house. There would be a small cost for I&C engineering however. Also, there would be some I&C costs for process monitoring and control.

(d) The existing ignition oil pipeline system would be replaced with a similar sized system for COM. Special design features of the COM system include a lack of long vertical drops and electrical trace heating for all COM delivery main and recirculation pipework.

Total COM system capital costs are shown in Table 7.2.

TABLE 7.2

COM System Capital Costs

	Lambton GS Jan $ 1984	Nanticoke GS Jan $ 1984
Coal Receiving Area	299,000	331,500
Coal Scale Weigher	12,000	16,000
Civil Costs (for Tanks and Piping)	20,000	25,000
Hammermills (Incl Motors)	40,000	50,000
Ballmills (Incl Motors and Starters)	448,000	590,000
Storage Tanks:		
Tanks	15,500	38,300
Insulation	8,400	17,500
Heater	1,500	4,100
Agitator	27,000	60,500
COM Piping:		
Piping (Incl Strainers)	1,327,700	1,705,000
Insulation	23,000	45,900
Trace Heating	9,000	17,000
COM Tank Filling Pumps	19,000	38,000
COM Transfer Pumps	19,000	38,000
COM Booster Pumps	32,000	104,000
COM Burners and Tips	2,100,000	3,500,000
I&C	170,000	175,000
Retrofit Costs	50,000	100,000
Electrical Service	550,800	816,200
TOTAL DIRECT	5,171,900	7,672,000
Construction Indirects	1,028,400	1,523,500
Engineering	513,900	762,000
Overheads	200,000	297,500
Interest	929,300	1,377,300
Contingency (Process)	2,149,400	3,183,900
Contingency (Project)	781,900	1,157,800
TOTAL PROJECT COST	10,744,000	15,920,000

7.1.2 Capital Cost Estimate for Plasma Arc Ignition Alternatives

Budget estimates for plasma arc igniters were supplied by Babcock and Wilcox Canada Limited. Actually, only Nanticoke GS was quoted as these are B&W boilers. In the Nanticoke case these retractable plasma arc torches could be located in the centre of the existing circular burners. In the application of plasma arc torches to a Combustion Engineering burner configuration, as at Lambton GS, the plasma arc torch would probably be placed adjacent to the main coal burner like the side oil igniter but on the other side. On this basis an Ontario Hydro estimate has been made from plasma arc conversion at Lambton GS. This consideration has been made for study completeness. It is conceded that the capital cost estimate for the Lambton cases could be low due to retrofit difficulties.

Two plasma arc alternatives have been considered, (a) a total conversion where a plasma arc torch is installed in every coal burner and (b) a partial conversion where a plasma arc torch is fitted to the burners from two pulverizers only.

The plasma arc ignition alternative calls for a substantial new electrical service. Even for the partial conversion considerable cable and switchgear costs arise. Actual installation estimates were carried out by the Electrical Design Department.

The capital costs for these (developmental) alternatives are given in Table 7.3

TABLE 7.3

Capital Costs of Plasma Arc Alternatives

	Lambton GS		Nanticoke GS	
	Total Conversion	Partial Conversion	Total Conversion	Partial Conversion
	January $ 1984			
Igniters and Equipment	24,134,100	8,256,400	40,162,500	16,065,000
Electrical Service	4,839,800	2,670,200	8,066,400	5,340,300
TOTAL DIRECT	28,973,900	10,926,600	48,228,900	21,405,300
Construction Indirects	5,794,900	2,185,300	9,645,800	4,281,000
Engineering	2,897,300	1,092,600	4,822,600	2,140,400
Overheads	1,129,600	426,000	1,880,500	834,600
Interest	2,677,200	1,009,600	4,456,300	1,977,800
Contingency	4,147,600	1,564,100	6,903,700	3,064,000
TOTAL PROJECT	45,620,500	17,204,200	75,937,800	33,703,100

Note: The budget cost applies only to Nanticoke GS. The values shown for Lambton GS are anticipated costs applied by Ontario Hydro and as such must be considered less accurate.

7.1.3 Capital Cost Estimate for Natural Gas Alternatives

Capital cost estimates used here are simply escalated from a detailed conversion study carried out by Ontario Hydro in 1982 (Ontario Hydro report CTS-01400-1).

Table 7.4 shows the capital costs for the natural gas ignition alternatives.

TABLE 7.4

Capital Costs of Natural Gas Alternatives

	Lambton GS	Nanticoke GS
	January $ 1984	
	*	
Total Direct Cost	6,412,100	9,262,500
Construction Indirects	1,282,200	1,852,500
Engineering	641,700	927,000
Overheads	249,800	361,000
Interest	1,159,500	1,675,000
Contingency	974,700	1,408,000
TOTAL PROJECT COST	10,721,000	15,486,000

* These costs are approximate only.

7.1.4 Capital Cost Estimate for Combustion Engineering System

This system is restricted to Lambton GS only. Combustion Engineering stated that they would require a substantial effort to design a system for a boiler of different manufacture than their own. This necessary effort is not considered justifiable at this time.

Table 7.5 shows the capital costs for the Combustion Engineering system and necessary supplies by Ontario Hydro to facilitate each system. The total inventory of equipment was itemized by CE but only a blanket cost was provided.

TABLE 7.5

Capital Cost of Two Combustion Engineering
(Direct Ignition of Pulverized Coal) Systems for Lambton GS

	January $ 1984
Two Combustion Engineering Systems	14,208,000
Civil Work Including Concrete	100,000
Structural Steel	120,000
Platforms and Ladders	30,000
Electrical Equipment and Services	1,959,000
Construction Labour	2,407,000
TOTAL DIRECT	18,824,000
Construction Indirects	3,765,000
Engineering	1,883,000
Overheads	734,000
Interest	5,029,000
Contingency	3,023,000
TOTAL PROJECT COST	33,257,000

7.1.5 Capital Cost Estimate for Steinmuller System

A capital cost estimate for the Steinmuller system at Nanticoke GS is presented here. Although it is probable that the system could be retrofitted to the Combustion Engineering boilers at Lambton GS it is conceded that it would not be a cost effective alternative to ignition oil.

Table 7.6 shows the capital cost estimate for two Steinmuller systems as retrofitted to Nanticoke GS. A retrofit allowance has been made for items such as relocation of pipework, hook up of the nitrogen inerting system, making access into the powerhouse, etc., etc.

The $5.2 M contingency is to cover unforeseen installation costs and possible increases in financing costs the actual ratio of contingency to direct capital is approximately 16 percent - the same as for the Combustion Engineering System at Lambton GS.

TABLE 7.6

Capital Cost of Two Steinmuller Systems
Retrofitted to Nanticoke GS

	January $ 1984
Two Steinmuller Systems	22,400,000
Coal Conveyor Systems	100,000
Retrofit Allowance	500,000
Civil Work Incl Concrete	150,000
Structural Steel	200,000
Platforms and Ladders	50,000
Elec Equipment and Services	2,898,000
Boiler Modifications	6,400,000
TOTAL DIRECT	32,608,000
Construction Indirects	6,521,000
Engineering	3,261,000
Overheads	1,271,000
Interest	8,710,000
Contingency	5,236,000
TOTAL PROJECT COST	57,607,000

7.2 Operating Costs

The calculated operating costs shown below are based on actual data and on the following assumptions. Actual development of this information is shown in Appendices I and II.

List of Assumptions

(a) The quantity of ignition fuel required is either at the high or low estimate specified by Ontario Hydro and will remain constant throughout the remaining life of the plant. For actual intermediate ignition fuel requirements, interpolation can be used. It is not anticipated that ignition requirements would be significantly above or below the ranges used here.

(b) The OM&A of alternative ignition systems can be estimated using Ontario Hydro's experience of ignition oil and other systems.

(c) Regardless of the type or mode of the ignition, the heat input to the boiler for any particular ignition sequence is always the same for each alternative. Therefore, some or all ignition oil is replaced by:

(1) Coal - Coal oil mixture, direct ignition systems (Combustion Engineering and Steinmuller) Plasma arc

(2) Gas - natural gas

(3) Electricity - plasma arc

(d) The differences in auxiliary electrical power consumption for the different alternatives must be accepted and accounted for. This is considered a refinement however.

(e) The alternative ignition systems are assumed to work almost as well as claimed. This has to be proven in most cases. As a contingency some oil firing has been allowed for all the alternatives other than natural gas.

Table 7.7 shows the annual operating maintenance and administration costs anticipated for the various ignition systems. Three alternatives - coal oil mixture, Combustion Engineering, and Steinmuller will require additional staff. This has been taken into account for the estimates.

TABLE 7.7

Operating Maintenance and Administration Estimates
Annual Costs

	OM&A	
	High Ignition $ 1984	Low Ignition $ 1984
Lambton GS		
Existing Ingition Oil	35,900	25,100
Coal Oil Mixture	71,800	50,300
Plasma Arc (Total)	33,000	23,100
Plasma Arc (Partial)	34,000	23,800
Natural Gas	30,500	21,400
Combustion Engineering	166,300	116,400
Nanticoke GS		
Existing Ignition Oil	107,100	85,700
Coal Oil Mixture	214,200	171,400
Plasma Arc (Total)	100,000	80,000
Plasma Arc (Partial)	104,200	83,400
Natural Gas	91,000	72,800
Steinmuller	288,000	230,400

Table 7.8 shows a compilation of total annual energy requirements for the various alternatives. Note a further breakdown is shown in Appendix II.

TABLE 7.8

Total Annual Energy Requirements of Ignition Alternatives

	Coal GJ	Oil GJ	Nat Gas GJ	Elec MWh
Lambton GS				
High Ignition				
Existing Ignition Oil	0	252,778	0	600
Coal Oil Mixture	106,131	146,647	0	764
Plasma Arc (Total)	179,092	68,403	0	2,056
Plasma Arc (Partial)	133,410	115,291	0	1,795
Natural Gas	0	0	252,778	0
Combustion Engineering	182,974	69,805	0	1,658
Low Ignition				
Existing Ignition Oil	0	77,156	0	300
Coal Oil Mixture	32,395	44,761	0	568
Plasma Arc (Total)	43,716	32,104	0	513
Plasma Arc (Partial)	35,111	40,940	0	583
Natural Gas	0	0	77,156	0
Combustion Engineering	65,498	11,659	0	825
Nanticoke GS				
High Ignition				
Existing Ignition Oil	0	968,182	0	1,000
Coal Mixture	406,500	561,682	0	1,255
Plasma Arc (Total)	637,364	316,850	0	5,073
Plasma Arc (Partial)	471,290	486,941	0	4,060
Natural Gas	0	0	968,182	0
Steinmuller	654,760	314,221	0	4,012
Low Ignition				
Existing Ignition Oil	0	507,195	0	600
Coal Oil Mixture	213,855	293,340	0	969
Plasma Arc (Total)	310,553	189,696	0	2,525
Plasma Arc (Partial)	239,294	263,098	0	2,004
Natural Gas	0	0	507,195	0
Steinmuller	351,710	155,911	0	3,130

7.3 Total Lifetime Costs

Table 7.9 summarizes the lifetime present worths of the alternative ignition systems. Detailed analysis is presented in the appendices. This table is considered as the base case comparison.

Note that the "Existing Oil" cases do not include capital component. However, it must also be remembered that all the alternatives, may be even natural gas, would require some ignition oil facilities.

TABLE 7.9

Ignition Alternatives
Lifetime Costs

	Scenario	
	High	Low
	Lifetime Cost (PW January 1984)	
Nanticoke GS		
Existing Oil	$97,894,000	$51,611,000
COM	$80,490,000	$48,591,000
Plasma Arc (Total)	$109,730,000	$87,669,000
Plasma Arc (Partial)	$89,226,000	$60,115,000
Natural Gas	$67,083,000	$40,934,000
Steinmuller	$92,244,000	$68,585,000
Lambton GS		
Existing Oil	$20,878,000	$6,522,000
COM	$23,268,000	$13,265,000
Plasma Arc (Total)	$45,557,000	$39,375,000
Plasma Arc (Partial)	$26,205,000	$17,790,000
Natural Gas	$20,108,000	$11,946,000
Combustion Engineering	$35,272,000	$27,689,000

8.0 DISCUSSION OF RESULTS

From the tables, it is apparent that natural gas is the most attractive alternative to ignition oil in existing stations at this point in time. Qualifying the above statement is necessary for at least two considerations. Firstly it is not certain that the present or forecast differentials in respective fuel prices will persist. Radical changes have been demonstrated in fuel prices and differentials in recent times. Also the plasma arc (partial) alternative has been treated conservatively in this study. It is conceivable that it could perform with greater success than expected, thus increasing its potential as an ignition system alternative.

As the study evolved, it was discovered that the high and low ignition scenarios initially proposed by two different departments, were actually slightly higher and lower respectively than what was actually believed. In other words the divergence of opinion was less than originally stated. However, the overall (large spread) effect is beneficial to the study as (a) all parties believe that the actual ignition usage will fall within the high and low range used here, and (b) by using a reasonably large range, the study results can be better interpreted for change in operating circumstances.

Appendix II shows the detail and rational of calculating total energy requirements. For this section it is sufficient to say that a strong sense of realism (or slight pessimism) prevailed for most cases, due to the lack of demonstrated performance of these alternatives. The calculation of electrical energy required for the alternatives is merely a refinement for completeness excepting the plasma arc cases where electrical energy plays a slightly more major role.

In estimating OM&A costs, Ontario Hydro data was used as much as possible. However, contrary to the calculation of total energy requirements, optimism was the keynote for calculating OM&A costs. Many authorities relate OM&A costs to capital costs on a percentage basis. Doing this with capital intensive systems such as those proposed by Combustion Engineering and Steinmuller could absolutely rule out such systems if even a moderate percentage was used. Therefore the lowest values conceivably possible were used for the high capital alternatives. It is conceded that actual OM&A costs for these schemes could be considerably higher.

Capital costs used for the coal oil mixture (COM) estimate are considered conservative. It is possible that large cost savings could be achieved by using the existing oil piping and making minimal modifications, installing new burner tips (instead of new burners), and removing the special process contingency applied only to this alternative. However the costs used here are considered applicable in the judgement of Ontario Hydro.

It is conceded that the coal oil mixture alternative has been fully loaded with high capital and contingency costs. However, in comparison to some other alternatives the COM costs are still very low. This weighting is a reflection on the lack of confidence with COM as a reliable start-up fuel - particularly with cold start conditions. Admittedly, in a retrofit situation additional piping would be used. However, the possibility of plugging somewhere in the system remains. Conversely if these uncertainties can be lived with then COM can be considered a viable ignition alternative.

The study has illustrated that at least in retrofit situations, a total conversion to plasma arc ignition cannot be justified on present day economics. In fact there is a lack of confidence that such a system would be viable with even a new boiler.

However the partial conversion where plasma arc ignition are used for the burners of two pulverizers looks better. Unfortunately there is insufficient evidence to say more at the present time other than further testing is warranted.

The system proposed by Combustion Engineering for Lambton GS could never be economically justified there. Actually it wasn't really anticipated as being viable for ignition only. One of the systems main uses - to be able to maintain load during a main pulverizer failure, is less critical at Lambton GS than it would be at a base load station. While it is not recommended, it is certain that the system could show small savings over ignition oil if applied to Nanticoke GS - assuming that the high ignition scenario is essentially correct.

Combustion Engineering Company made a tentative second attempt at an alternative ignition system. This is reported in Appendix V.

The Steinmuller system was the source of considerable delay with this study. The proposals sent by Steinmuller of Gummersbach, West Germany were fairly detailed. However as described in Section 6 there was some difficulty in obtaining limited acceptance for the system at Nanticoke GS - the proposal for Lambton GS was abandoned after attempting some re-arrangement of the ignitor burners.

In retrospect it must be said that even the limited application considered for Nanticoke GS would be a horrendous retrofit job. A prolonged outage would be required to make all the necessary relocations of flooring, burner pipes, etc. It must be said that a Steinmuller direct coal ignition system could not be economically applied to any boiler other than one which already had Steinmuller main burners which can readily accept a large coal ignition burned down the centre. Undoubtedly the Steinmuller ignition system is a big economic success with such boilers, especially when operating in places where ignition oil is very expensive. However there is insufficient incentive for any further interest in the Steinmuller system by Ontario Hydro - at least for retrofit conversions.

When calculating the total energy requirements for the Steinmuller system, it was decided to recalculate the same for the somewhat similar Combustion Engineering system. Thus the total energy requirements are on as similar a basis as possible for these systems. The most significant effect this recalculation made on the Combustion Engineering alternative was to considerably increase the estimate of ignition oil required which merely brings the coal/oil ratio into line with the Steinmuller system.

Even the high capital required and the limited form of conversion considered, the Steinmuller system came in just under ignition oil in total lifetime costs - at least for the high ignition scenario. This is an indication that same alternative to oil ignition must be viable for new boilers if not for retrofits.

Table 8.1 shows the 30 year lifetime costs for three alternative ignition systems at a new 4 x 500 MW coal fired generating station. It is assumed that:

(a) This would be the size of a future coal fired generating station;

(b) The station would have modest ignition fuel requirements as is the case at Lambton GS but not at Nanticoke GS.

The same high and low ignition scenarios are used. However in this case the oil ignition systems includes a total design and construction capital cost of 1984 $6,928,000.

As illustrated in the table, the alternatives to oil do improve their position especially in the high ignition scenario. However, considering high and low ignition scenarios the situation is unclear with only natural gas being cheaper than oil at all times.

TABLE 8.1

30 YEAR LIFETIME COSTS OF NEW STATION IGNITION SYSTEMS

		High Ignition $1984	Low Ignition $1984
4 x 500 MW	(Oil	38,751,000	16,834,000
	(N. Gas	25,981,000	13,778,000
	(COM	33,543,000	18,568,000
	(Plasma Arc (partial)	32,402,000	19,949,000

Table 8.3 is an abbreviated list of advantages and disadvantages. They have been put on one page for the readers convenience.

TABLE 8.2

SUMMARY OF ADVANTAGES AND DISADVANTAGES

Alternative	Advantage	Disadvantage
Coal oil mixture	Proven feasibility Universal ignition capability Similar operation to oil firing	58 percent of oil still fired Potential for coal plugging High particulate emissions
Plasma arc	Probable lowest fuel cost	Not proven Warm/hot sequences only High particulate emissions Oil still required
Natural gas	Virtually guaranteed success Total elimination of oil No particulate emissions	Supply off site High fuel cost
Direct coal ignition (CE and Steinmuller)	Back up coal firing capability Low fuel cost	Very high capital cost High OM&A cost High particulate emissions Oil still required Retrofit difficult (especially Steinmuller)
Existing oil	Installed and operating Universal capability	Very high fuel cost

9.0 CONCLUSIONS

(1) None of the ignition alternatives to oil studied here could be justified economically for a retrofit to Lambton GS or Nanticoke GS.

However the following alternatives (in order of viability) could offer long term savings in money in most cases

(a) Natural gas
(b) Coal oil mixture (COM)
(c) Partial plasma arc

(2) With present relative fuel prices, natural gas offers a clear cost advantage over oil for ignition at new thermal generating stations.

(3) Plasma arc ignition - the electrical alternative - is only viable under the high ignition scenario at Nanticoke GS and as a partial conversion. However, the process is considered technically successful and it would save oil.

(4) Operations personnel are presently trying to reduce ignition oil consumption at Nanticoke GS by using smaller igniters. If this action proves to be successful, then the future oil consumption would be reduced. This action could eliminate the ignition alternatives studied from any further consideration - at least as far as retrofit applications are concerned.

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APPENDIX I

Development of Operating Maintenance and Administration Estimates

The recorded OM&A at the three large coal fired generating stations are;

	$1982
Lakeview GS (8 x 300 MW)	32,015,000
Lambton GS (4 x 500 MW)	22,038,000
Nanticoke GS (8 x 500 MW)	33,782,000

From Ontario Hydro's Generation Development Department the cost of a new coal fired generating plant in $1982 is:

$704/kW for 500 MW units
$943/kW for 300 MW units

Thus the annual cost of OM&A versus the cost of generating plant is:

Lakeview	1.41 percent
Lambton	1.57 percent
Nanticoke	1.20 percent

Economy of scale in both size and number of generating units are observed here.

Now these percentages are only rough guidelines to annual OM&A costs versus capital cost of equipment. It must be said however, that the values are conservative, especially when remembering that much of the capital cost for generating facilities is for structural and other immobile facilities.

From Ontario Hydro's Central Thermal Services Department the total annual OM&A costs related to the existing ignition oil systems are:

	1981	1982
Lakeview GS	$109,577	$ 67,265
Lambton GS	43,120	21,459
Nanticoke GS	75,471	116,894

The results in this table can be partially explained. Nanticoke GS uses approximately five times the amount of ignition oil that Lambton uses. Other differences do not have any simple explanation as generation and oil consumption was approximately the same for both years.

Therefore, 1981 and 1982 annual costs are simply averaged and escalated at six and five percent to give January 1984 costs, the annual OM&A cost for ignition oil systems is anticipated to be:

	1984
Lambton GS	$ 35,938
Nanticoke GS	107,051

The above annual OM&A costs must be the main basis of estimating OM&A costs of other ignition systems.

For this study it is assumed that the cost of a natural gas ignition system would be less than for the existing oil system - say 15 percent. Conversely, it is assumed that the OM&A costs for (a still developmental) coal oil mixture system would be higher than the existing oil system. In addition to having transport and burning problems there is the processing aspects to consider. Bearing in mind all of the aspects of OM&A, it is suggested here that a multiple of two times the existing oil system be used as;

(a) the system is developmental and unproven
(b) fine grinding of coal is required
(c) continuous product monitoring is required
(d) COM transport and burning is known to be more difficult than straightforward light oil.

Even using this multiple still gives an OM&A of only 1.4 percent of the capital cost at Nanticoke GS and 0.7 percent at Lambton GS (low use factor). In reality, an even greater OM&A than this simple doubling is anticipated. However at this point in time, there is no real commercial

experience to draw from. Therefore the doubling used here is judgemental - high enough to be a consideration, but not so high as to eliminate the alternative from the outset.

As a matter of comparison, the OM&A estimates used here are in the same range as those produced by TVA (9) for a similar situation, and much smaller than those assumed by ARCO (10) who used four percent of capital for a complete station COM conversion. ARCO maintain their argument in a Vol II document (11) that OM&A is strongly related to capital cost. However a graph indicates some downward revision of the original OM&A estimates.

The plasma arc system OM&A costs probably centre upon the electrode life and their replacement. Considering warm and hot starts and flame support, also a 200 hour electrode life (this is longer than is actually achieved at the time of writing), OM&A costs for electrode replacement alone may be estimated as follows:

Nanticoke GS (high ignition scenario)

	Warm Starts	Hot Starts	Flame Support
Operating hours	(2.4 x 240)	+ (1.2 x 280)	+ 1622
	= 2534		

	Torches/Start		Hours Life
Electrodes used (pairs/year) =	16 x 2534	-	200
=	203		

Therefore annual cost of electrode changes:

	Electrode Cost	Labour
= 203 x	($200	+ $80)
= $56,840		

Development is ongoing to increase the electrode life. However, considering the uncertainties and the fact that other maintenance will arise from the plasma arc system the electrical supply system and controls, some continuing ignition oil system maintenance (also an almost impossible to account for increase in coal firing system maintenance), it is considered that an annual cost of $100,000 should be used for Nanticoke GS. This figure is only for a complete plasma arc conversion. Reducing the scope of the conversion to two rows of burners only/boiler

(versus five rows existing) and considering a lower ignition fuel requirement, would change the annual OM&A costs. A partial conversion would mean that some OM&A costs would arise from the existing ignition oil system (versus a total plasma arc conversion).

The Combustion Engineering system is considered to be both complex and developmental. However the capital cost is so high as to probably eliminate its further consideration at the outset. For this reason alone, a low percentage value of 0.5 is assumed for OM&A. As shown in Appendix I-1 however, this low percentage of capital still gives a very high annual cost in terms of dollars.

The Steinmuller system presents very similar problems to the Combustion Engineering system in regard to estimating OM&A costs. Again however, the capital is too high for a retrofit conversion to go ahead. Also in the Steinmuller case for Nanticoke GS, considerable oil firing is still required thus reducing the incentive for a conversion. There is a temptation to use a slightly lower ratio of OM&A to capital for the Steinmuller system than was used for the Combustion Engineering system. The Steinmuller system does not have coal pumps and small diameter dense phase coal transport lines. However the Combustion Engineering system has actually been seen and much more insight is therefore possible on that system. The Steinmuller system has not been seen and it is conceded that the system is not fully understood. Perhaps worst of all there were a significant number of changes of direction when discussing aspects of the system with Steinmuller. Summarizing, in view of the high capital and fuel costs, an optimistic 0.5 percent ratio for OM&A to capital will be adopted for the Steinmuller system at Nanticoke GS. This will present the best possible case for the Steinmuller system since it is known that it is not a viable retrofit ignition alternative anyway.

The following table summarizes OM&A costs for the high ignition fuel scenario. A column of percent OM&A (annual OM&A versus total capital cost) is included as a comparison with total generating station OM&A and capital costs.

In the lack of more substantiated information, the OM&A costs for COM and plasma arc systems have been adjusted to the same ratio as OM&A for ignition oil for Lambton GS and Nanticoke GS.

TABLE APPENDIX I-1

Operating Maintenance and Administration Estimates (high ignition fuel requirement)

Station	System	Total Capital	OM&A Estimate	OM&A as % of Capital
		1984 $000		%
Lambton GS				
	COM	10,273	71.8	0.72
	Plasma Arc (Total)	45,621	33.0	0.07
	Plasma Arc (Partial)	17,204	34.0	0.20
	Natural Gas	10,721	30.5	0.28
	Comb Eng	33,257	166.3	0.5
	No. 2 Oil	-	35.9	-
Nanticoke GS				
	COM	15,343	214.2	1.40
	Plasma Arc (total)	75,938	100.0	0.13
	Plasma Arc (partial)	33,703	104.2	0.31
	Natural Gas	15,486	91.0	0.59
	Steinmuller	57,607	288.0	0.5
	No. 2 Oil	-	107.1	-

The calculation of OM&A as a percentage of capital investment reveals much lower values than that calculated for the generating station as a whole. To verify this a search of equipment failure was carried out for Lakeview, Lambton and Nanticoke for 1982. From the results below, it may be concluded that almost all maintenance carried out on ignition systems is non curtailing and thus low OM&A costs could be anticipated.

Ignition Problems Curtailing
Unit Operation
1982

Station	Outage
Lakeview GS	One six minute delay on Unit 5
Lambton GS	None
Nanticoke GS	One 20 minute problem on Unit 5

For the low ignition scenario, OM&A costs will be slightly reduced. It is proposed here that since the ignition oil requirement at Nanticoke GS is now about 50 percent of the high requirement, the OM&A should be reduced by 20 percent for all alternatives. At Lambton the cutback is even greater - the ignition oil requirement is only 30 percent of the high requirement. Therefore it is proposed that the OM&A at Lambton GS for the low ignition scenario be 30 percent lower than for the high ignition oil requirement case.

All of the new ignition systems would require some staff training and this is assumed to be part of OM&A. For the natural gas alternative training is mandatory for all shift and trade supervisors and maintainers. At Nanticoke GS there are at least 100 personnel in one of these categories. The Thermal Training Centre state that a three day course followed by an examination is required. Costs are estimated as;

Lost labour	$204/person/day
Training	$ 27/person/day
Examination	$ 35/person

It is also considered possible that the Federal Government would pay up to 25% of all the above costs under a T.I.B.I. grant.

APPENDIX II

Calculation of Total Ignition Fuel and Related Electrical Energy Costs

This is a crucial issue in the comparison of the alternative ignition systems. The philosophy used here has been to consider the alternative ignition system energy put into the boiler in any form as replacement for ignition oil. Thus the existing ignition oil is replaced - as far as possible - by the alternate energy. In the plasma arc cases there is substantial electrical energy input. However this input may be considered as part of the heat input of the boiler and actual coal and oil quantities are calculated for plasma arc cases based on this assumption.

Auxiliary electrical energy to operate these ignition systems such as pumps fans etc. are also taken into account as a refinement and the differences in the respective alternatives as part of the overall comparison.

Some exclusions from the comparison are inevitable. They include differences in main fuel and electrical generation during unit loading, changes in electrical requirements of main pulverizers etc. changes in lighting and instrumentation electrical service requirements etc, etc. However it is suggested that the comparison is on an equitable basis and as accurate as reasonably possible.

Ignition Oil

Even the existing ignition system presents problems in estimating costs. For this study, the view points of two different schools of thought are considered as a high ignition oil scenario and a low ignition oil scenario. Table Appendix II - 1 shows the numbers of start ups considered and the related oil consumption for them.

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TABLE APPENDIX II-1

Ignition Oil Quantities and Start Up Times

High Consumption Scenario

Nanticoke GS

8 units

	No./Year	Hours/Start	kL/Start	Annual Total kL
Cold Start	80	8	58.0	4,640
Cold to Warm Start	120	4	23.6	2,832
Warm Start	240	2.4	13.6	3,264
Hot Start	280	1.2	7.4	2,072
Flame Support	-		-	12,000
				24,808

Lambton GS

4 units

Cold Start	40	9	30.4	1,216
Warm Start	170	2.7	9.0	1,530
Hot Start	170	2.0	4.3	731
Flame Support	-		-	3,000
				6,477

Low Consumption Scenario

Nanticoke GS

Cold Start	60	8	58	3,480
Cold to Warm Start	60	4	23.6	1,416
Warm Start	100	2.4	13.6	1,360
Hot Start	100	1.2	7.4	740
Flame Support	-		-	6,000
				12,996

Lambton GS

4 units

Cold Start	30	9	30.4	912
Warm Start	50	2.7	9.0	450
Hot Start	50	2.0	4.3	215
Flame Support	-		-	400
				1977

It may be observed that the quantity of ignition oil used at Nanticoke GS is much higher than Lambton GS for the same duty. Thermal Generation Division are considering this at present and are preparing a program to reduce the burner capacity at Nanticoke GS. At present the philosophy is to aim for about a 30 percent reduction in oil at minimal capital conversion cost. Such a reduction from the "high scenario" still leaves the Nanticoke GS ignition oil consumption 34 percent above the "low scenario". Thus the validity of the findings in this study should still stand in principle even if not in absolute terms.

Now using the information in the above table, adding station estimates of station service for the ignition (adjusted to annual values by Energy Studies Dept) and considering ignition oil at a HHV of 39,027 kJ/litre a further table (Appendix II-2) can be constructed.

TABLE APPENDIX II-2

Ignition Oil Heat and Elec Energy
Annual Requirement

Station	High Ignition Oil Scenario		Low Ignition Oil Scenario	
	Heat GJ	Elec kWh	Heat GJ	Elec kWh
Nanticoke	968,182	1,000,000	507,195	600,000
Lambton	252,778	600,000	77,156	300,000

The heat equivalent above is required from all alternatives considered in the study. Inclusion of electrical energy is a refinement to make the comparison of the alternatives as fair as possible.

From Ontario Hydro's Fuel Division, the January 1984 cost of ignition oil is $5.99/GJ. Also from Ontario Hydro's System Planning Division, the cost of the electrical energy for this application is at system incremental energy cost based on fossil fuel only. This means that the nuclear and hydraulic generation is excluded or ignored. Any shortfall at one coal fired station is made up by generation at another coal fired station. For January 1984, System Planning calculate such differences to be worth 18.6 mills/kWh or $18.6 MWh.

Coal Oil Mixture

The total heat energy is the same as ignition oil but the cost is different due to the make up of the fuel. There is an increase in auxiliary station power consumption however.

Table Appendix II - 3 shows the breakdown of COM and the resultant share of heat from coal and oil by proportioning them according to their respective weights and heating values. Also shown in this table is an estimate of electrical energy consumption. As stated, only US coal has been considered for COM production due to its more attractive combustion properties.

TABLE APPENDIX II-3

Coal Oil Mixture - Total Energy Requirements

(a) COM Breakdown

Material	Percent by weight	HHV kJ/kg
US coal	50	29,558
Water	5	0
No. 2 oil	45	45,380
COM	100	35,200

(b) COM Coal and Oil Requirements

Station	Scenario	Heat Requirement Ign System GJ	US Coal GJ	Oil GJ
Nanticoke GS	High	968,182	406,500	561,682
	Low	507,195	213,855	293,340
Lambton GS	High	252,778	106,131	146,647
	Low	77,156	32,395	44,761

(c) COM Electrical Energy Requirements

Equipment	Consumption kW		Operating Hours			
	Nanticoke	Lambton	Nanticoke High	Nanticoke Low	Lambton High	Lambton Low
Conveyor	25	25	600	400	600	400
First stage crusher	8	8	6,000	4,000	6,000	4,000
Oil pumping	15	12	300	200	300	120
Ball mill	100	75	6,000	4,000	6,000	4,000
Agitation	25	10	8,760	8,760	8,760	8,760
Trace Heating	34	20	5,000	5,000	5,000	5,000
COM pumping (Main recirc)	25	8	6,000	4,000	6,000	4,000
(Boiler)	10 (x8)	5 (x4)	600	400	600	250

Summary

		Annual Elec Energy kWh
Nanticoke GS	High	1,254,500
	Low	969,000
Lambton GS	High	764,200
	Low	567,740

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Plasma Arc Ignition

Due to the complete lack of test data there is more uncertainty on this alternative than with any of the others considered for this study. The assumptions listed below have been made to estimate the total energy requirements of a plasma arc ignition system.

There is a complicating factor at Nanticoke GS. Existing station electrical services would only permit a complete plasma arc (16 igniters) supply to alternative boilers at any one time. If adjacent boilers are required to be brought on line simultaneously then some ignition oil firing will be required.

Assumptions Adopted:

(1) All cold or cold/warm starts will be carried out with ignition oil firing. Ignition oil will be used up to "warm start" conditions and at this point coal will be introduced and ignited by plasma arc. Oil is discontinued at this point.

(2) Warm up will proceed thereafter with the continuous use of one pulverizer operating at part load and continuous support from the plasma arc igniter.

(3) The second pulverizer coming on stream will require 15 minutes of flame support from plasma arc igniters.

(4) For Nanticoke GS it is assumed that adjacent boilers will be required simultaneously on 75 percent of occasions thus necessitating the use of ignition oil for stabilizing the flame of the second pulverizer on line. This situation does not arise at Lambton GS.

(5) It is assumed that each plasma arc igniter uses 125 kW of electrical energy.

(6) It is assumed that flame support requirements - for wet and frozen coal difficulties also bringing mills in and out of service would be met as follows:

	PA/Coal Energy	Oil Energy
Total PA Conversion	80%	20%
Partial PA Conversion	50%	50%

Adopting an eight burner scenario for flame support, at Nanticoke GS the existing ignition oil burners would consume 8 x 460.8 litres per hour. This is equivalent to 142.3 GJ/hour and for the high ignition scenario at Nanticoke GS means an average flame support period of 407 hours/unit/year. Assuming this flame support was replaced by an eight burner plasma arc/coal flame, then the ratio of energies provided would be 3.6 GJ from plasma arc: 138.7 GJ from coal.

(7) It is assumed that for one reason or another the plasma arc system would not be available during some start up periods. For study purposes it is assumed that this occurs 10 percent of the time for total conversion and 20 percent of the time for a partial conversion. This contingency is made due to the lack of experience with plasma arc coal ignition.

(8) Additional station electrical service is required when using a plasma arc ignition system. The electrical energy required for the first pulverizer and its primary air fan will be used for the evaluation of alternatives. Also station electrical service is still required for the existing ignition oil serivce. This latter item is simplified as it would be extremely difficult to predict the actual usage requirements more accurately. Also it must be remembered that this aspect is merely an attempted refinement of the main picture.

It is assumed that for total plasma arc conversions, 30 percent of the existing ignition oil electrical requirements would still be required. For partial conversions it is assumed that 50 percent of the existing ignition oil electrical requirements would still be required.

The above may be summarized as follows for calculating the total energy requirements which are shown in Tables Appendix II-4 and 5.

Specified Energy Sources for Plasma Arc Conversion

Oil

(a) All cold and cold warm starts (up to warm start conditions).

(b) Ten percent of all starts for total conversion case would be entirely oil fired (20 percent for partial conversion).

(c) Twenty percent of all flame support (total conversion) or 50 percent for a partial conversion.

(d) At Nanticoke GS only,

75 percent of every second start x 15 minutes x 8 burners. This is the ignition of the second pulverizer. The total heat quantity involved per (second) start is 8 x 0.25 x 460.8 x 38,609 kJ = 36.6 GJ.

Plasma Arc

(a) 8 x 0.125 MW x 2.4 hours for all starts in the total conversion case and 90 percent of this for the partial conversion.

(b) 8 x 0.125 MW x 0.25 hours for 25 percent of all second starts.

Coal

The difference between the existing ignition oil requirements and the sum of calculated oil required plus the equivalent of the electrical energy required for the plasma arc.

Auxiliary Power

(a) Thirty percent of existing ignition oil electrical requirement for the total converison (50 percent for the partial conversion) plus the minimum load electrical requirement for the primary air fan (200 kW at Lambton GS, 400 kW at Nanticoke GS) and a pulverizer (300 kW).

The followng calculation shows the development of total energy requirements for the plasma arc ignition alternatives. The ignition oil quantities shown in Table Appendix II-1 are converted here for convenience from kL to GJ. 1 kL of No. 2 ignition oil is equivalent to 38.609 GJ.

Tables Appendix II-4 and 5 show the summary of the total energy requirements for the plasma arc alternatives.

Nanticoke GS

- Total plasma arc conversion
- High ignition scenario

Oil Consumption

		a	b	c
Cold starts	80	[(2239.3 - 525.1)	+ (0.1 x 525.1)	+ 1/2 (0.75 x 35.6)]
Cold to warm starts	120	[(911.2 - 525.1)	+ (0.1 x 525.1)	+ 1/2 (0.75 x 35.6)]]
Warm starts	240	[(0.1 x 525.1)	+ 1/2 (0.75 x 35.6)]	
Hot starts	280	(0.1 x 285.7	+ 1/2 (0.75 x 35.6)]	
Flame support		0.2 x 463,3087		

. . TOTAL OIL CONSUMPTION = 316,850 GJ

Notes:

(a) Oil will always be used to warm the boiler from cold to warm conditions.

(b) On 10 percent of all starts the oil will continue to bring the boiler on stream.

(c) This is the assumed 75 percent probability that the start of a second boiler requires oil due to a lack of station service for plasma arc energy.

Plasma Arc Elec Energy
1 MWh = 3.6 GJ

Cold Starts	80	[(3.6 x 2.4)[a] 0.9 + 1/2 (0.25 x 3.6[b] x 0.25)]
Cold to Warm Starts	120	[(3.6 x 2.4) 0.9 + 1/2 (0.25 x 3.6 x 0.25)]
Warm Starts	240	[(3.6 x 2.4) 0.9 + 1/2 (0.25 x 3.6 x 0.25)]
Hot Starts	280	[(3.6 x 1.2) 0.9 + 1/2 (0.25 x 3.6 x 0.25)]
Flame Support		$0.8 \times 463{,}308 \times \frac{3.6}{142.3}$[c]

. . TOTAL PLASMA ARC ENERGY = 13,968 GJ

. . TOTAL ENERGY FROM COAL = (968,182 - 316,850 - 13,968)
= 637,364 GJ

Notes:

(a) This is the probability of using 8 x 0.125 MW (3.6 GJ) of plasma arc energy for 2.4 hours.

(b) This is the probability of using 3.6 GJ of plasma arc in a second boiler (of a pair supplied by one transformer) for 15 minutes.

(c) This is the total flame support energy times the estimated ratio of plasma arc energy to coal energy. The 0.8 factor is the probability of plasma arc being used for this duty.

Auxiliary Power (MWh)

Primary air fan and pulverizer

Cold start	80 [0.9 (0.4 + 0.3)^{a} 2.4 + 1/2 (0.4 + 0.3)^{b} 0.25 x 0.25]
Cold to warm start	120 [0.9 (0.4 + 0.3) 2.4 + 1/2 (0.4 + 0.3) 0.25 x 0.25)
Warm start	240 [0.9 (10.4 + 0.3) 2.4 + 1/2 (0.4 + 0.3) 0.25 x 0.25]
Hot start	280 (0.9 (0.4 + 0.3) 1.2 + 1/2 (0.4 + 0.3) 0.25 x 0.25]
Ignition oil system	0.3 x 1000

. . TOTAL AUX POWER = 1192.7 MWh

Notes:

(a) This is the probability of coal firing equipment use for 2.4 hours.

(b) This is the probability of coal firing equipment use in a second boiler (of a pair supplied by the same trasformer) for 15 minutes.

(c) There is no auxiliary power required for flame support provided by plasma arc.

TABLE APPENDIX II-4

Total Plasma Arc Conversion - Total Energy Requirments

Station	Ignition Scenario	Existing Ignition Oil System GJ	Conversion			
			Oil GJ	Coal GJ	Plasma Arc GJ	Aux Power MWh
Lambton	high	252,778	68,403	179,092	5,283	588.2
	low	77,156	32,104	43,716	1,336	142.3
Nanticoke	high	968,182	316,850	637,364	13,968	1192.7
	low	507,195	189,696	310,553	6,946	595.3

TABLE APPENDIX II-5

Partial Plasma Arc Conversion - Total Energy Requirements

Station	Ignition Scenario	Existing Ignition Oil System GJ	Conversion			
			Oil GJ	Coal GJ	Plasma Arc GJ	Aux Power MWh
Lambton	high	252,778	115,291	133,410	4,077	662.8
	low	77,156	40,940	35,111	1,105	276.4
Nanticoke	high	968,182	486,941	471,290	9,951	1295.3
	low	507,195	263,098	239,294	4,803	670.0

Natural Gas

As stated earlier the heat requirement for natural gas is exactly the same as for the existing ignition oil (combustion efficiency is relatively low for both fuels during light up). In the case of natural gas, there is no auxiliary power requirement (electrical service for controls and lights, etc. are negligible and therefore ignored).

For the record, the higher heating value of natural gas is assumed to be 37,242 KJ/cubic metre.

Combustion Engineering System

This system was quoted for the Lambton GS boilers only. Considering the nature of the CE system offered at Lambton GS - i.e., warm up guns rather than direct coal igniters, the following rationale is used to estimate the total energy requirements of the system.

Total Oil Consumption:

2 GJ modified side oil igniters are on with the coal fuelled warm up guns for 15 minutes during start ups (CE claim only 5 minutes is required). 15 minutes ignition of side oil igniter for other main coal burners - top three rows. Assume the possibility of having to use one of the top rows as one of the first pair of pulverizers to be 20 percent. Assume 50 percent of flame stability requirements are met by ignition oil.

Total Coal Consumption:

Remainder of all ignition requirements not supplied by oil.

Total Electrical Requirements:

The operating requirements for the pulverizer and vent fan etc. are calculated from the coal consumptions and electrical service estimates based on this. Items such as coal pumps and secondary air fans are required more often - through all start up periods.

It is assumed that 80 percent of the electrical power requirement for the existing ignition oil system is still required.

Power required for electrical igniters, instrumentation and control and additional lighting is not included as it is too difficult to quantify. This last omission will not jeopardize the overall accuracy of the total energy requirements calculated for this ignition alternative.

Total Coal/Oil Requirement for Cold Start

Present side oil igniters at Lambton fire 52.9 mL/sec. This is equivalent to 7.35 GJ/hour. The modified side oil igniters beside the new coal warm up guns fire oil would be rated at 2 GJ/hour. From Bull Run GS, Tennessee, the rate of coal firing is a maximum 0.907 Mg/hour/burner. With US coal this equates to 27.46 GJ/hour. The present heat requirement from ignition for a cold start is 47,457 GJ/year. The quantity is based on 1186.4 GJ per cold start and assuming 40 cold starts per year.

Total Coal/Oil Requirement

Oil $[(24 \times 0.25 \times 2) + (8 \times 0.25 \times 7.35) + 0.2\,(8 \times 0.25 \times 7.35)]$
(b, h, GJ) (b, h, GJ) (b, h, GJ)

+ Coal $[N \times 9 \times 27.46] = 1186.4$
(h, GJ)

where b is number of burners
h is number of operating hours

N is the average number of coal warm up guns used throughout the start up period. In this equation it is assumed that all the small oil igniters are eventually used. Also the 20 percent probability that one of the top rows of main burners is used is accounted for.

$$\therefore \quad N = \frac{1186.4 - (12 + 14.7 + 2.94)}{247.14}$$

$$= 4.68$$

Boiler start up is limited by metal temperatures. Too steep a temperature gradient could not be tolerated by the pressure ports.

Therefore the total quantities of coal and oil used during an average cold start (40 predicted in high ignition scenario);

29.64 GJ oil, 1156.6 GJ coal.

Coal/oil requirements for all starts are:

High Ignition Scenario:

	Ignition Oil System GJ	Oil GJ	Coal GJ
Cold Starts	47,457	1,186	46,271
Warm Starts	59,711	5,039	54,672
Hot Starts	28,529	5,039	23,490
Flame Support	117,081	58,541	58,541
SUB TOTAL	252,778	69,805	182,974

Low Ignition Scenario:

	Ignition Oil System GJ	Oil GJ	Coal GJ
Cold Starts	35,592	889	34,703
Warm Starts	17,562	1,482	16,080
Hot Starts	8,391	1,482	6,909
Flame Support	15,611	7,806	7,806
SUB TOTAL	77,156	11,659	65,498

Electrical Requirement

(a) Hours of Operation at Rated Design Output by New Pulverizer

		High Scenario	Low Scenario
Total Coal Consumption		182,974 GJ	65,498 GJ
at 30.28 GJ/Mg	=	6043 Mg	2163 Mg
Hours of pulverizer operation at 43 Mg/hour	=	140.5	50.3
	say	160 hours	60 hours

This is the assumed period of annual operation for the pulverizer and vent fan etc.

(b) Coal Pumps, Secondary Air Fans Etc.

This equipment is required throughout the start up periods plus an allowance for flame stability periods and different unit operating periods.

		High	Low
Total start up time/unit		292	127
	assume	500	250

(c) Ignition Oil Pumping

This system is required almost as much as before only for shorter periods at the boiler corners. Transfer and recirculation would be continuous however. Therefore, use 80 percent of the existing ignition oil electrical requirements.

Electrical Requirements/CE System

	kW	High Scenario hrs	High Scenario kWh	Low Scenario hrs	Low Scenario kWh
Coal Feeder	10	160	1,600	60	600
Pulverizer	350	160	56,000	60	21,000
Conveyor	10	160	1,600	60	16,000
Vent fan	1,000	160	160,000	60	60,000
Coal Pumps	300	500	150,000	250	75,000
Secy Air Fans	200	500	100,000	250	50,000
Compressed Air	200	500	100,000	2,000	20,000
Inerting Fan	10	2,000	20,000	2,000	20,000
SUB TOTAL			589,200		292,600
80% Ignition Oil			480,000		240,000

TABLE APPENDIX II-6

Total Energy Requirement of 2 CE Systems at Lambton GS

Ignition Scenario	Oil GJ	Coal GJ	Elec Energy kWh
High	69,805	182,974	1,658,400
Low	11,659	65,498	825,200

Steinmuller System

Steinmuller claim that their system is well proven to meet all ignition requirements. However, since at Nanticoke GS the physical location of the Steinmuller burners makes them warm up guns rather than igniter burners, the following rationale will be used to determine the total energy requirements.

Total Oil Consumption:

0.5 MW (th) equivalent for up to 16 pilot burners during all start up operation. 15 minutes ignition (at present rate of firing) for first two pulverizers or 16 main burners coming on load. 50 percent of flame stability requirements. 148 kW (th) equivalent for hot gas producer for the pulverizer operation, doubled to allow for Steinmuller system warm up. This last item must be treated as an additional oil consumption to the equal GJ requirements of all the alternatives.

Total coal Consumption:

Remainder of all ignition requirements not supplied by oil.

Total electrical requirements:

Conveyor, pulverizer, feeder, carrier fan kW based on hours required to produce necessary warm up coal plus an allowance. Trace heating intermittent/continuous compressed air, oil pumps based on total start up periods. Electrical igniters, instrumentation and control service and any additional lighting required is ignored. Ignition oil pumping.

Coal/Oil Requirement Sample Calculation for Cold Start

Steinmuller burner oil consumption is 0.5 MW (th). This is 1.8 GJ per hour. Existing oil burners at 128 mL/sec are 17.79 GJ/hr. For an 8 hour cold start, total heat input is 7.5 MW (th) from coal and 0.5 MW (th) from oil, plus 16 x 15 minutes of exising oil burners to light up the main coal burners.

Total coal/oil requirement is

$$(1.8 \times 8 \times N) + (16 \times 0.25 \times 17.79) \text{ oil}$$
$$+ \quad \left(\frac{7.5}{0.5} \times 1.8 \times 8 \times N\right) \text{ coal}$$

where N is the average number of Steinmuller burners used during the start up.

Now the quantity of ignition oil (in terms of GJ) for a cold starts at present is 181,086 GJ/year. This is based on 80 start per year using 2263.6 GJ per start.

$$(14.4N + 71.16) \text{ GJ oil} + 216 N \text{ GJ coal} = 2263.6 \text{ GJ existing oil}$$

$$N = \frac{2263.6 - 71.16}{14.4 + 216}$$

$$= 9.516$$

This is the average number of Steinmuller burners used over the 8 hour cold start. The actual programming would be based on boiler metal temperatures and the burners would probably go on in groups of four. All 16 Steinmuller burners would be on before the end of the start up period.

Therefore the total coal/oil requirement for a cold start is 208.1 GJ of oil and 2055.5 GJ of coal.

Coal/Oil Requirements

High Ignition Scenario

	Ignition Oil System GJ	Oil GJ	Coal GJ
Cold Start	181,086	16,648	164,438
Cold to Warm Start	110,524	14,916	95,608
Warm Start	127,384	23,952	103,432
Hot Start	80,864	23,744	57,120
Flame Support	468,324	234,162	234,162
SUB TOTAL	968,182	313,422	654,760

Low Ignition Scenario

	Ignition Oil System GJ	Oil GJ	Coal GJ
Cold Start	135,814	12,486	123,328
Cold to Warm Start	55,262	7,458	47,804
Warm Start	53,077	9,980	43,097
Hot Start	28,880	8,480	20,400
Flame Support	234,162	117,081	117,081
SUB TOTAL	507,195	155,485	351,710

Electrical Requirement (plus oil from gas producer)

Hours of operation (at design output) required by Steinmuller pulverizer (one required/4 units).

High Scenario	Low Scenario
$\frac{654,760 \text{ GJ}}{2 \times 30.28 \text{ GJ/Mg} \times 20 \text{ Mg/hr}}$	$\frac{351,710}{2 \times 30.28 \times 20}$
= 541 hours	291 hours
assume 600 hours	325 hours

From this it may be assumed that the hot gas producer would be required for 750 hours for the high scenario and 400 hours for the low scenario.

Assume that the intermittent/continuous trace heating is used for 2500 hours per year.

Assume that 80 percent of the electrical requirement for the existing ignition oil system is still required.

Compressed air kW is based on total start up periods.

Therefore, oil required for hot gas producers is:

High Scenario	Low Scenario
750 x 0.148 x 3.6)2	(400 x 0.148 x 3.6)2
= 799.2 GJ	426.2 GJ

Electrical Requirement (for each 4 unit system):

		High Scenario		Low Scenario	
	kW	hrs	kWh	hrs	kWh
Pulverizer	200	600	120,000	325	65,000
Feeder	20	600	12,000	325	6,500
Carrier Fan	440	600	264,000	325	143,000
Conveyor	20	600	12,000	325	6,500
Trace Heating	400	2,500	1,000,000	2,500	1,000,000
Compressed Air	250	800	200,000	400	100,000
Oil Pumps	10	800	8,000	400	4,000
SUB TOTAL (to be multipled by 2)			1,606,200		1,325,000
Ignition Oil			800,000		480,000

Thus the summation of the foregoing sub totals are totalled in Table Appendix II-7.

TABLE APPENDIX II-7

Total Energy Requirements for Two Steinmuller System at Nanticoke GS

	Ign Oil GJ	Coal GJ	Elec Energy MWh
High Ignition Scenario	314,221	654,760	4,012
Low Ignition Scenario	155,911	351,710	3,130

APPENDIX III

ENERGY STUDIES DEPARTMENT
Filing Memorandum

August 15, 1983
File: 986/01408P

Investigation into Direct Ignition of Pulverized Coal Trip Report - Visit to Combustion Engineering Research Laboratory - Visit to Tenessee Valley Authority's Bull Run GS

The above visits were made by Mr. S. Legedza, Mr. R. Tidy of C.E. Canada, and the writer on the 27th and 28th of July, 1983.

KDL Research Laboratory
Windsor Conneticutt
July 27, 1983

Prior to visiting the laboratory, a questionnaire on Combustion Engineering's direct ignition system was prepared by Ontario Hydro and sent on in advance.

Mr. D.A. Smith, Supervisor of Combustion Component Research gave a presentation of the direct ignition of pulverized coal (DIPC) system. He pointed out that the igniters used a 30 amp, 220 volt supply which was energized for about three minutes each start up. Using a system of transformers and capacitors etc. (D.A. Smith did not elaborate too fully), a series of high energy sparks were produced at the ignition electrode gate.

Fine coal grinding is required for the DIPC system. D.A. Smith stated that some coals have shown low reactivity (in terms of ignitability). Even some bituminous coals fall into this category. Although not stated at the time, it appears that volatile content was the greatest part of reactivity. D.A. Smith said that all coals considered for the DIPC system would have to be tested. However, the only coal that could be ruled out without qualification is anthracite. It is possible that the DIPC system could work with lignite.

It was claimed that the DIPC burner acted as a sort of classifier and that the pulverized coal in the ignition zone was 80 percent through 400 mesh (source pulverizer shows 75 percent of total through 200 mesh). It was also stated that the coal/air mixture supplied to the DIPC burner was 97 percent of stoichiometric - 8.0 kg of air to 1 kg of fuel.

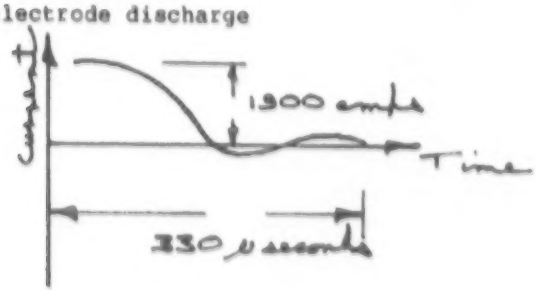
In the first commercial application at Bull Run GS, coal pumps are used to supply coal to the burners with one pump to eight burner igniters. The pulverized coal/air mixture is supplied at a rate of 0.907 mg/hour through each 25.4 mm line.

Coal pumps are reducing volume screw devices which in combination with a compressed air supply, supply coal and air to the burners at about 340 kPa with a velocity of about 20 metres/second. As the coal is compressed more and more through the pump it also becomes an effective seal for the compressed air.

Fibre optic flame scanners are used for the DIPC burner. The original location of the scanner in the laboratory test rig was to scan directly across the quarl. While this was successful in the laboratory it was not successful at Bull Run GS. Thus the scanners were redirected to a point well outside the quarl where a stronger flame is present. Although not stated at the time, this action would probably negate CE's claim that the scanner could differentiate between the DIPC burner flame and the main burner flame.

In the afternoon we met Mr. D. Mylchreest who is the assistant project engineer for the Bull Run GS DIPC system. D. Mylchreest produced the attached equipment and flow diagram. When discussing DIPC system power requirments, he stated that the baghouse vent fan having 1 0000 hp motor was the largest power consumer. The igniters had the following characteristics;

Electrode discharge



40 joules discharged each spark
30 sparks/second

The peak power was stated to be 9.27 joules. Originally it was 3.6 joules but has been increased with the use of line chokes.

D. Mylchreest also mentioned that the 25.4 mm coal lines to the burners were designed with large radii - 0.686 metres - to prevent coal plugging. The only exception to this is the final bend right at the burner itself. The burner quarl is thought to be made of cast inconnel.

Combustion Engineering believe that if oil ignition was used instead of the high energy electric arc, coal fineness would be much less critical. Thus existing oil burners could be used instead, with little or no modifications.

D.A. Smith stated that CE would consider a DIPC system shared between two boilers, but no more at least for the present. Coal pump to burner lines had been proven in lengths of up to 130 metres. There is some reluctance to pursue longer lengths at present.

It is considered that a DIPC system could be installed at a generating station with little interference to an operating generating unit.

Bull Run GS
Near Knoxville Tennessee
July 28, 1983

Bull Run GS is a single 900 MW supercritical generating unit which operates base load. Even at its minimum control load of 500 MW its heat rate is still one of the best on the TVA system. Coal is delivered by rail with only 2 1/2 days of coal stockpiled on site.

One unusual feature of the boiler is that it has two furnaces - physically separated by a few metres.

The DIPC system installed at Bull Run GS is the first commercial application of the system. TVA opted to replace 32 out of 48 oil burners with DIPC burners to save ignition oil used for two purposes - start up and load regain (maintaining high output during periods of wet coal, pulverizer problems, etc.) They kept eight oil burners/furnace in case the DIPC system was unsuccessful.

Our first discussion at Bull Run Gs was with Mr. G. Tennent of CE. G. Tennent discussed some details of the installation, then took us on a partial tour of the equipment before taking us over to meet the station staff. After some discussion with station staff, G. Tennent concluded the tour of the equipment.

The installation proved to be quite extensive. A large annex has been added on to the end of the existing station to house most of the DIPC system equipment - particularly the 3 x 91 Mg pulverized coal silos. Eyeballing the annex it appeared to be about 30 metres high 35 metres long and 10 metres deep.

During the tour G. Tennent mentioned that replacing the coal pump screw was a half hour job. CE are trying different materials for the screw. Carbon steel lasts for 80-90 operating hours. Tungsten carbide about double this. It is hoped that up to 1 000 hours can be achieved with a ceramic or other material.

Inspecting the coal lines to the burners, it was observed by touch that the line temperature was about 65°C. G. Tennent verified this, then said that a cold pipe indicated a coal plug. This was interesting as it had been claimed by CE that this never happens.

Fortuitously at the time of our visit the DIPC system was being used. Three out of four operational coal pumps were running and supplying about 23 Mg/hour of coal to the boiler. This made up more than half the output drop from the l oss of a 40 Mg/hour unit pulverizer. This is the "load regain" mode of operation of the DIPC system.

Control equipment for the DIPC system is profuse. We saw a large number of cubicles containing relays, power supplies, permissive etc. Inside the unit control room there is a freestanding DIPC control console. At present TVA have an additional operator in the control room. However, this is considered to be a temporary situation until the DIPC system is considered fully commissioned.

G. Tennent stated that energization of the igniters was staggered as on one occasion, it was observed that for a split second in time, igniter output was 30 MW. Apparently this has no effect on station service however, there was some reservation on the matter.

TVA staff appeared quite supportive of the DIPC system - in particular the load regain capability. This they have used for up to three days continuously. During discussions with the Station Manager, Mr. Wade, it was stated that tmore demonstration was required before he would be confident that the DIPC system could warm up a boiler from cold. This reservation is however mostly due to the base load operation of the plant. There has been little opportunity to test the system during cold start conditions. Thus, the remaining top row of oil burners (eight) will be retained for the present.

No special housekeeping problems have developed other than the coal dust around the feeders. This was stated to be a problem that must be resolved. It was recognized that the DIPC system would add to existing station maintenance. However, there were other forces within the TVA organization which were inducing cutbacks in station maintenance.

Mr. Wade said that tremendous interest has been shown in the DIPC system by other utilities. He was continually answering long distance phone calls on the subject.

CE Canada
<u>Mr. R. Tidy</u>

R. Tidy said that the Bull Run GS experiment was a pioneering effort which CE considered to be successful. However costs could be lowered in a second installation by various means e.g. eliminating the baghouse arrangement required for the pressurized boiler at Bull Run Gs. R. Tidy

stated that CE Canada were interested in applying the system to all Ontario Hydro boilers and to this end were prepared to work out budget capital costs for systems based on Ontario Hydro's requirements.

In addition to providing costs, R. Tidy would also provide estimates of power consumption for the DIPC system(s).

T.B. Walls
Design Specialist
Energy Studies & Development

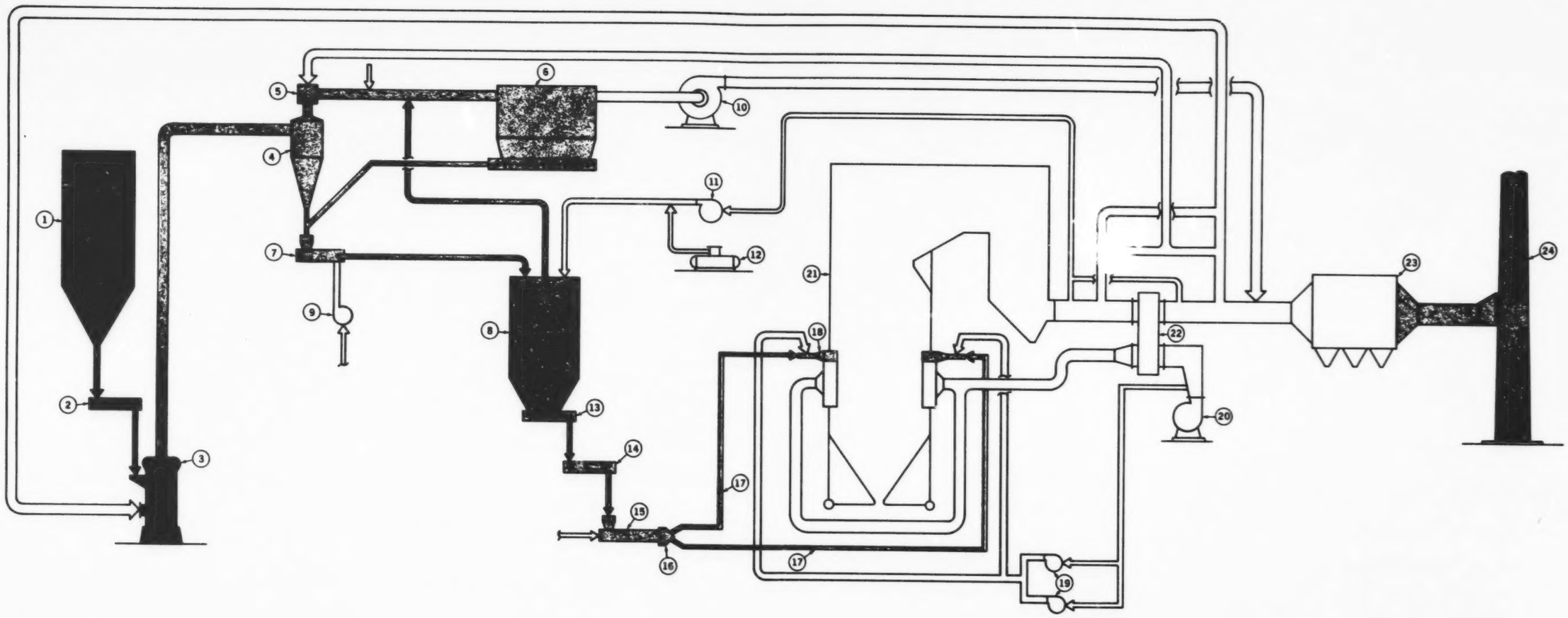
TBW:rlg

Enc

cc S. Legedza
C.W. Dawson
J. Bennett
R. Gibson

2685o

Insert Equipment and Flow Diagram



AREA 100
COAL RECEIVING

1. Raw Coal Bunker

AREA 200
COAL PREPARATION

2. Raw Coal Feeder
3. Pulverizer
4. Cyclone Separator
5. Mixing Chamber
6. Bag House
7. Coal Transfer Pump
8. Pulverized Coal Storage Bin
9. Coal Transfer Pump Blower
10. Vent Fan
11. Inerting Fan
12. CO_2 Inerting System

AREA 300
FUEL TRANSPORT

13. Screw Pre-Feeder
14. Belt Feeder
15. C-E Coal Pump
16. Fuel Distributor
17. Dense Phase Transport Lines
18. DIPC Burners
19. DIPC Secondary Air Fans

AREA 400
BOILER, HEAT RECOVERY & GAS CLEANING

20. Forced Draft Fan
21. Boiler
22. Air Preheater
23. Precipitator
24. Stack

EQUIPMENT AND FLOW DIAGRAM
DIRECT IGNITION PULVERIZED COAL SYSTEM
TVA BULL RUN

APPENDIX IV

Summary of Literature Review and Computer Search

A manual search through relevant topics was conducted using Ontario Hydro's extensive library facilities. All likely conference proceedings were reviewed and annotated in this report's bibliography whenever appropriate.

Most of the material produced during the search was related material as distinct from being directly involved with the conversion of oil ignition to something different. The only exception to this was coal oil mixtures where considerable in house material was available as indicated in the bibliography. Conversely almost nothing was found on plasma arc ignition of coal. A major part of this must be put down to the early stage of development of plasma arc ignition techniques. However the lack of demonstrated ability on the part of plasma arc ignition appears to have created a lack of confidence or interest with prospective customers.

On some occassions the literature review did lead to further enquiries with manufacturers, researchers and utilities. Where relevant information transpired from this further investigation it has been reported at least in part, and referenced where possible in the bibliography.

Two computer searches were made using Ontario Hydro's access terminal to major data bases in North America. Data bases searched included

(a) Canada Institute of Scientific Information (CISTI)

(b) Lockheed Corporation

(c) Electrical Power Research Institute (EPRI)

(d) Cambridge Scientific Abstracts.

These major data bases have in turn, link search capability with other smaller data bases.

The first search made in February 1983 was helpful in undertaking the manual search. However most of the material recorded during the February search was related rather directly involved to alternatives of oil ignition systems. It was considered that the first computer search was worth repeating due to the developmental status of alternative ignition systems.

The latter computer search was made in November 1983 and was restricted to 1983 data.

Ontario Hydro

APPENDIX V

CASH FLOW TABLES FOR ALTERNATIVES

Memorandum To: MR. S. LEGEDZA
Power Equipment Department
Design and Development Division

Date: May 31, 1984

Location or Dept: H11 A27

File: 960-08708-ATS

Subject: Life Time Costs of Ignition Devices for Fossil Stations

As per your request, we have calculated the life time net present values of the following ignition methods for Nanticoke GS and Lambton GS.

(a) Existing oil fuelled ignition (Lambton, Nanticoke)
(b) Coal-oil mixture (Lambton, Nanticoke)
(c) Natural Gas (Lambton, Nanticoke)
(d) Plasma arc (Lambton, Nanticoke)
(e) Plasma arc (partial conversion) (lambton, Nanticoke)
(f) Combustion Engineering (Lambton)
(g) Steinmuller (Nanticoke)

Each of the above was calculated for two different utilization scenarios. The results are presented on the attached tables.

All cost data are provided by your section.

Please contact me at 7768 if you have any questions.

Ken Tsui
Planning and Control
Design and Development Division

KT:mo

Enc

cc V.R. Sligl
T.B. Walls
A.G. Barnstaple

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : EXISTING NO.2 OIL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0
1988	0	46	2143	0	0	16	2204	1196	1196
1989	0	49	2399	0	0	17	2466	1174	2370
1990	0	53	2548	0	0	19	2620	1094	3464
1991	0	57	3032	0	0	22	3111	1140	4604
1992	0	62	3608	0	0	25	3694	1198	5802
1993	0	67	4293	0	0	28	4388	1259	7060
1994	0	73	5109	0	0	32	5213	1324	8384
1995	0	79	5569	0	0	34	5682	1277	9661
1996	0	85	6070	0	0	37	6192	1242	10903
1997	0	92	6616	0	0	41	6749	1209	12112
1998	0	99	7212	0	0	44	7356	1176	13288
1999	0	107	7861	0	0	48	8016	1145	14433
2000	0	116	8568	0	0	53	8736	1124	15557
2001	0	124	9339	0	0	59	9523	1104	16660
2002	0	134	10180	0	0	65	10379	1084	17744
2003	0	144	11096	0	0	71	11312	1064	18808
2004	0	155	12095	0	0	78	12328	1045	19853
2005	0	167	13183	0	0	86	13436	1026	20878

TOTAL LIFETIME PRESENT WORTH 20878

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : COAL OIL MIXTURE

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	5501	0	0	0	0	0	5501	4308	4308
1987	5914	0	0	0	0	0	5914	4098	8407
1988	0	91	1243	0	366	20	1720	934	9340
1989	0	98	1392	0	385	22	1898	903	10244
1990	0	106	1478	0	382	24	1991	831	11075
1991	0	115	1759	0	413	28	2314	848	11923
1992	0	124	2093	0	446	31	2694	874	12797
1993	0	134	2491	0	482	35	3142	901	13698
1994	0	145	2964	0	520	40	3669	932	14630
1995	0	157	3231	0	554	44	3985	895	15525
1996	0	170	3521	0	590	48	4329	868	16394
1997	0	184	3838	0	628	52	4703	842	17236
1998	0	199	4184	0	669	56	5108	817	18053
1999	0	215	4560	0	713	62	5549	792	18845
2000	0	231	4971	0	763	67	6032	776	19621
2001	0	249	5418	0	816	75	6558	760	20381
2002	0	268	5906	0	873	83	7130	744	21126
2003	0	289	6437	0	934	91	7751	729	21855
2004	0	311	7017	0	1000	99	8427	714	22569
2005	0	335	7648	0	1070	109	9162	699	23268

TOTAL LIFETIME PRESENT WORTH 23268

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : PLASMA ARC TOTAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	51299	0	0	0	0	0	51299	35553	35553
1988	0	42	580	0	618	53	1293	702	36255
1989	0	45	649	0	650	59	1404	669	36923
1990	0	49	689	0	645	65	1449	605	37528
1991	0	53	820	0	697	75	1645	603	38131
1992	0	57	976	0	753	84	1870	606	38737
1993	0	62	1162	0	813	95	2131	612	39349
1994	0	67	1383	0	878	108	2435	618	39967
1995	0	72	1507	0	935	117	2631	591	40558
1996	0	78	1643	0	996	128	2844	571	41129
1997	0	85	1790	0	1060	140	3075	551	41679
1998	0	91	1952	0	1129	152	3324	532	42211
1999	0	99	2127	0	1203	166	3594	513	42724
2000	0	106	2319	0	1287	181	3892	501	43225
2001	0	114	2527	0	1377	202	4221	489	43714
2002	0	123	2755	0	1473	222	4574	478	44192
2003	0	133	3003	0	1577	244	4956	466	44658
2004	0	143	3273	0	1687	267	5370	455	45113
2005	0	154	3567	0	1805	293	5820	444	45557

TOTAL LIFETIME PRESENT WORTH 45557

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : PLASMA ARC PARTIAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	19346	0	0	0	0	0	19346	13408	13408
1988	0	44	977	0	460	47	1528	829	14237
1989	0	47	1094	0	484	52	1678	799	15036
1990	0	51	1162	0	481	57	1751	731	15767
1991	0	55	1383	0	519	65	2022	741	16508
1992	0	59	1645	0	561	74	2339	758	17266
1993	0	64	1958	0	605	83	2711	778	18044
1994	0	70	2330	0	654	94	3148	799	18843
1995	0	75	2540	0	696	103	3414	767	19610
1996	0	81	2768	0	742	112	3703	743	20353
1997	0	88	3018	0	790	122	4018	720	21073
1998	0	95	3289	0	841	133	4358	697	21770
1999	0	103	3585	0	896	145	4729	675	22445
2000	0	111	3908	0	959	158	5135	661	23106
2001	0	119	4260	0	1026	176	5581	647	23753
2002	0	128	4643	0	1098	194	6063	633	24386
2003	0	138	5061	0	1174	213	6587	620	25005
2004	0	149	5516	0	1257	234	7155	606	25612
2005	0	160	6013	0	1345	256	7774	593	26205

TOTAL LIFETIME PRESENT WORTH 26205

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : NATURAL GAS

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	5371	0	0	0	0	0	5371	4207	4207
1987	5774	0	0	0	0	0	5774	4002	8208
1988	0	39	0	1408	0	0	1447	785	8994
1989	0	42	0	1580	0	0	1622	772	9766
1990	0	45	0	1747	0	0	1792	748	10514
1991	0	49	0	1954	0	0	2003	734	11248
1992	0	53	0	2184	0	0	2237	725	11973
1993	0	57	0	2447	0	0	2504	718	12691
1994	0	62	0	2738	0	0	2799	711	13402
1995	0	67	0	2985	0	0	3052	686	14088
1996	0	72	0	3253	0	0	3325	667	14755
1997	0	78	0	3546	0	0	3625	649	15404
1998	0	84	0	3865	0	0	3949	632	16036
1999	0	91	0	4211	0	0	4302	614	16650
2000	0	98	0	4590	0	0	4689	603	17253
2001	0	106	0	5005	0	0	5111	592	17845
2002	0	114	0	5455	0	0	5569	581	18427
2003	0	123	0	5945	0	0	6068	571	18998
2004	0	132	0	6480	0	0	6612	560	19558
2005	0	142	0	7064	0	0	7206	550	20108

TOTAL LIFETIME PRESENT WORTH 20108

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : HIGH
SYSTEM : COMBUSTION ENGINEERING

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	9589	0	0	0	0	0	9589	8486	8486
1986	10541	0	0	0	0	0	10541	8255	16741
1987	10999	0	0	0	0	0	10999	7623	24364
1988	0	211	592	0	631	0	1434	778	25142
1989	0	228	663	0	664	0	1555	740	25882
1990	0	246	704	0	659	0	1609	672	26554
1991	0	266	837	0	712	0	1815	665	27219
1992	0	287	996	0	769	0	2052	665	27884
1993	0	310	1186	0	830	0	2326	667	28552
1994	0	336	1411	0	897	0	2644	671	29223
1995	0	364	1538	0	955	0	2857	642	29865
1996	0	394	1676	0	1017	0	3087	619	30484
1997	0	426	1827	0	1083	0	3336	598	31082
1998	0	461	1992	0	1154	0	3606	577	31659
1999	0	497	2171	0	1229	0	3897	556	32215
2000	0	535	2366	0	1315	0	4216	542	32757
2001	0	576	2579	0	1407	0	4562	529	33286
2002	0	621	2811	0	1505	0	4937	516	33802
2003	0	668	3064	0	1611	0	5344	503	34304
2004	0	720	3340	0	1723	0	5784	490	34794
2005	0	775	3641	0	1844	0	6260	478	35272

TOTAL LIFETIME PRESENT WORTH 35272

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : EXISTING NO.2 OIL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0
1988	0	32	654	0	0	8	694	376	376
1989	0	34	732	0	0	9	775	369	746
1990	0	37	778	0	0	10	824	344	1090
1991	0	40	925	0	0	11	976	358	1448
1992	0	43	1101	0	0	12	1157	375	1823
1993	0	47	1310	0	0	14	1371	393	2216
1994	0	51	1559	0	0	16	1626	413	2629
1995	0	55	1700	0	0	17	1772	398	3027
1996	0	59	1853	0	0	19	1931	387	3414
1997	0	64	2019	0	0	20	2104	377	3791
1998	0	70	2201	0	0	22	2293	367	4158
1999	0	75	2399	0	0	24	2499	357	4515
2000	0	81	2615	0	0	26	2722	350	4865
2001	0	87	2851	0	0	29	2967	344	5209
2002	0	94	3107	0	0	32	3233	338	5546
2003	0	101	3387	0	0	36	3523	331	5878
2004	0	109	3692	0	0	39	3839	325	6203
2005	0	117	4024	0	0	43	4184	319	6522

TOTAL LIFETIME PRESENT WORTH 6522

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : COAL OIL MIXTURE

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	5501	0	0	0	0	0	5501	4308	4308
1987	5914	0	0	0	0	0	5914	4098	8407
1988	0	64	379	0	112	15	570	309	8716
1989	0	69	425	0	118	16	628	299	9015
1990	0	74	451	0	117	18	660	276	9290
1991	0	80	537	0	126	21	764	280	9570
1992	0	87	639	0	136	23	885	287	9857
1993	0	94	760	0	147	26	1027	295	10152
1994	0	102	905	0	159	30	1195	303	10455
1995	0	110	986	0	169	32	1297	292	10747
1996	0	119	1075	0	180	35	1409	283	11029
1997	0	129	1172	0	192	39	1530	274	11303
1998	0	139	1277	0	204	42	1662	266	11569
1999	0	150	1392	0	218	46	1805	258	11827
2000	0	162	1517	0	233	50	1961	252	12079
2001	0	174	1654	0	249	56	2133	247	12327
2002	0	187	1803	0	267	61	2318	242	12569
2003	0	202	1965	0	285	67	2519	237	12805
2004	0	217	2142	0	305	74	2738	232	13037
2005	0	234	2334	0	326	81	2976	227	13265

TOTAL LIFETIME PRESENT WORTH 13265

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : PLASMA ARC TOTAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	51299	0	0	0	0	0	51299	35553	35553
1988	0	29	272	0	151	13	466	253	35805
1989	0	32	305	0	159	15	510	243	36048
1990	0	34	324	0	158	16	532	222	36270
1991	0	37	385	0	170	19	611	224	36494
1992	0	40	458	0	184	21	703	228	36722
1993	0	43	545	0	198	24	811	233	36955
1994	0	47	649	0	214	27	937	238	37192
1995	0	51	707	0	228	29	1015	228	37421
1996	0	55	771	0	243	32	1101	221	37641
1997	0	59	840	0	259	35	1193	214	37855
1998	0	64	916	0	276	38	1294	207	38062
1999	0	69	998	0	294	41	1403	200	38262
2000	0	75	1088	0	314	45	1522	196	38458
2001	0	80	1186	0	336	50	1653	192	38650
2002	0	87	1293	0	360	55	1795	187	38837
2003	0	93	1409	0	385	61	1948	183	39020
2004	0	100	1536	0	412	67	2115	179	39200
2005	0	108	1674	0	441	73	2296	175	39375

TOTAL LIFETIME PRESENT WORTH 39375

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : PLASMA ARC PARTIAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	19346	0	0	0	0	0	19346	13408	13408
1988	0	31	347	0	121	15	514	279	13687
1989	0	33	389	0	128	17	566	270	13956
1990	0	36	413	0	127	19	593	248	14204
1991	0	39	491	0	137	21	687	252	14456
1992	0	42	584	0	148	24	798	259	14715
1993	0	45	695	0	159	27	927	266	14981
1994	0	49	827	0	172	31	1079	274	15255
1995	0	53	902	0	183	33	1171	263	15518
1996	0	57	983	0	195	36	1272	255	15773
1997	0	62	1072	0	208	40	1381	247	16020
1998	0	67	1168	0	221	43	1500	240	16260
1999	0	72	1273	0	236	47	1628	233	16493
2000	0	78	1388	0	252	51	1769	228	16720
2001	0	84	1513	0	270	57	1924	223	16943
2002	0	90	1649	0	289	63	2091	218	17162
2003	0	97	1797	0	309	69	2273	214	17375
2004	0	105	1959	0	331	76	2470	209	17585
2005	0	113	2135	0	354	83	2685	205	17790

TOTAL LIFETIME PRESENT WORTH 17790

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : NATURAL GAS

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	5371	0	0	0	0	0	5371	4207	4207
1987	5774	0	0	0	0	0	5774	4002	8208
1988	0	27	0	430	0	0	457	248	8456
1989	0	29	0	482	0	0	512	244	8700
1990	0	32	0	533	0	0	565	236	8936
1991	0	34	0	596	0	0	631	231	9167
1992	0	37	0	667	0	0	704	228	9395
1993	0	40	0	747	0	0	787	226	9621
1994	0	43	0	836	0	0	879	223	9844
1995	0	47	0	911	0	0	958	215	10059
1996	0	51	0	993	0	0	1044	209	10268
1997	0	55	0	1082	0	0	1137	204	10472
1998	0	59	0	1180	0	0	1239	198	10670
1999	0	64	0	1285	0	0	1349	193	10863
2000	0	69	0	1401	0	0	1470	189	11052
2001	0	74	0	1528	0	0	1602	186	11238
2002	0	80	0	1665	0	0	1745	182	11420
2003	0	86	0	1815	0	0	1901	179	11599
2004	0	93	0	1978	0	0	2071	175	11774
2005	0	100	0	2156	0	0	2256	172	11946

TOTAL LIFETIME PRESENT WORTH 11946

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : LAMBTON
SCENARIO : LOW
SYSTEM : COMBUSTION ENGINEERING

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	9589	0	0	0	0	0	9589	8486	8486
1986	10541	0	0	0	0	0	10541	8255	16741
1987	10999	0	0	0	0	0	10999	7623	24364
1988	0	148	99	0	226	0	473	256	24620
1989	0	159	111	0	238	0	508	242	24862
1990	0	172	118	0	236	0	526	220	25081
1991	0	186	140	0	255	0	581	213	25294
1992	0	201	166	0	275	0	643	208	25502
1993	0	217	198	0	297	0	712	204	25707
1994	0	235	236	0	321	0	792	201	25908
1995	0	255	257	0	342	0	853	192	26100
1996	0	275	280	0	364	0	920	184	26284
1997	0	298	305	0	388	0	991	178	26462
1998	0	322	333	0	413	0	1068	171	26633
1999	0	348	363	0	440	0	1150	164	26797
2000	0	375	395	0	471	0	1240	160	26956
2001	0	403	431	0	504	0	1338	155	27111
2002	0	434	470	0	539	0	1443	151	27262
2003	0	468	512	0	577	0	1556	146	27408
2004	0	504	558	0	617	0	1679	142	27551
2005	0	543	608	0	660	0	1811	138	27689

TOTAL LIFETIME PRESENT WORTH 27689

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : EXISTING NO.2 OIL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0
1988	0	136	8207	0	0	26	8368	4542	4542
1989	0	147	9189	0	0	29	9364	4458	9001
1990	0	158	9758	0	0	32	9948	4155	13155
1991	0	171	11612	0	0	36	11819	4330	17485
1992	0	185	13818	0	0	41	14044	4553	22038
1993	0	200	16444	0	0	46	16690	4788	26827
1994	0	217	19568	0	0	53	19837	5037	31863
1995	0	234	21329	0	0	57	21621	4858	36721
1996	0	253	23249	0	0	62	23565	4727	41449
1997	0	274	25341	0	0	68	25683	4600	46049
1998	0	297	27622	0	0	74	27993	4477	50526
1999	0	320	30108	0	0	81	30509	4356	54882
2000	0	345	32818	0	0	88	33250	4277	59160
2001	0	371	35771	0	0	98	36241	4200	63360
2002	0	400	38991	0	0	108	39499	4124	67484
2003	0	431	42500	0	0	119	43049	4049	71533
2004	0	464	46325	0	0	130	46919	3976	75509
2005	0	499	50494	0	0	143	51136	3904	79413
2006	0	538	55039	0	0	153	55729	3833	83246
2007	0	579	59992	0	0	164	60735	3763	87009
2008	0	624	65391	0	0	176	66191	3695	90704
2009	0	672	71277	0	0	188	72137	3628	94332
2010	0	724	77691	0	0	202	78617	3562	97894

TOTAL LIFETIME PRESENT WORTH 97894

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : COAL OIL MIXTURE

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	7965	0	0	0	0	0	7965	6237	6237
1987	8562	0	0	0	0	0	8562	5934	12171
1988	0	272	4761	0	1388	33	6453	3502	15673
1989	0	293	5331	0	1461	36	7121	3390	19064
1990	0	317	5661	0	1449	40	7467	3118	22182
1991	0	342	6737	0	1565	46	8689	3183	25366
1992	0	370	8017	0	1690	52	10128	3284	28649
1993	0	399	9540	0	1826	58	11823	3392	32041
1994	0	433	11352	0	1972	66	13823	3510	35551
1995	0	469	12374	0	2100	72	15014	3373	38924
1996	0	507	13488	0	2236	78	16309	3272	42196
1997	0	548	14702	0	2382	85	17717	3173	45369
1998	0	593	16025	0	2536	93	19247	3078	48448
1999	0	640	17467	0	2701	101	20909	2986	51433
2000	0	689	19039	0	2890	110	22729	2924	54357
2001	0	742	20752	0	3093	123	24710	2864	57221
2002	0	799	22620	0	3309	136	26864	2805	60026
2003	0	861	24656	0	3541	149	29206	2747	62773
2004	0	927	26875	0	3789	163	31754	2691	65464
2005	0	999	29294	0	4054	179	34525	2636	68100
2006	0	1076	31930	0	4338	192	37535	2582	70681
2007	0	1159	34804	0	4641	205	40809	2529	73210
2008	0	1248	37936	0	4966	220	44370	2477	75687
2009	0	1344	41350	0	5314	236	48244	2426	78113
2010	0	1448	45072	0	5686	253	52458	2377	80490

TOTAL LIFETIME PRESENT WORTH 80490

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : PLASMA ARC TOTAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	85391	0	0	0	0	0	85391	59180	59180
1988	0	127	2686	0	2611	132	5556	3015	62196
1989	0	137	3007	0	2799	147	6090	2899	65095
1990	0	148	3193	0	2930	161	6433	2687	67782
1991	0	160	3800	0	3158	184	7302	2675	70457
1992	0	173	4522	0	3355	209	8258	2677	73134
1993	0	186	5381	0	2862	235	8666	2486	75620
1994	0	202	6404	0	3091	266	9964	2530	78150
1995	0	219	6980	0	3292	290	10781	2422	80572
1996	0	237	7608	0	3506	316	11667	2341	82913
1997	0	256	8293	0	3734	344	12628	2262	85175
1998	0	277	9040	0	3977	375	13668	2186	87361
1999	0	299	9853	0	4235	409	14796	2113	89474
2000	0	322	10740	0	4532	445	16039	2063	91537
2001	0	347	11707	0	4849	498	17400	2017	93554
2002	0	373	12760	0	5188	548	18870	1970	95524
2003	0	402	13909	0	5552	602	20464	1925	97449
2004	0	433	15160	0	5940	660	22194	1881	99329
2005	0	466	16525	0	6356	724	24071	1838	101167
2006	0	502	18012	0	6801	776	26091	1794	102962
2007	0	541	19633	0	7277	831	28282	1752	104714
2008	0	583	21400	0	7787	890	30660	1711	106426
2009	0	628	23326	0	8332	954	33240	1672	108097
2010	0	676	25426	0	8915	1022	36039	1633	109730

TOTAL LIFETIME PRESENT WORTH 109730

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : PLASMA ARC PARTIAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	37898	0	0	0	0	0	37898	26265	26265
1988	0	132	4127	0	1931	106	6296	3417	29682
1989	0	143	4621	0	2070	117	6951	3310	32992
1990	0	154	4908	0	2167	129	7358	3073	36065
1991	0	166	5840	0	2335	147	8489	3110	39175
1992	0	180	6950	0	2481	167	9777	3170	42345
1993	0	194	8270	0	2117	188	10769	3090	45434
1994	0	211	9842	0	2286	213	12551	3187	48621
1995	0	228	10727	0	2434	232	13622	3061	51682
1996	0	247	11693	0	2593	253	14785	2966	54648
1997	0	267	12745	0	2761	276	16049	2875	57523
1998	0	289	13892	0	2941	300	17422	2786	60309
1999	0	311	15143	0	3132	327	18913	2701	63009
2000	0	335	16505	0	3351	356	20548	2643	65653
2001	0	361	17991	0	3586	399	22336	2589	68241
2002	0	389	19610	0	3837	439	24274	2534	70776
2003	0	419	21375	0	4105	481	26381	2481	73257
2004	0	451	23299	0	4392	528	28671	2430	75687
2005	0	486	25396	0	4700	579	31161	2379	78066
2006	0	523	27681	0	5029	621	33854	2328	80394
2007	0	564	30173	0	5381	665	36782	2279	82673
2008	0	607	32888	0	5758	712	39965	2231	84904
2009	0	654	35848	0	6161	764	43426	2184	87088
2010	0	704	39074	0	6592	818	47189	2138	89226

TOTAL LIFETIME PRESENT WORTH 89226

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : NATURAL GAS

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	7722	0	0	0	0	0	7722	6047	6047
1987	8301	0	0	0	0	0	8301	5753	11800
1988	0	115	0	5393	0	0	5508	2990	14790
1989	0	125	0	6051	0	0	6176	2940	17730
1990	0	135	0	6690	0	0	6825	2850	20581
1991	0	145	0	7484	0	0	7629	2795	23376
1992	0	157	0	8365	0	0	8522	2763	26138
1993	0	170	0	9372	0	0	9542	2738	28876
1994	0	184	0	10485	0	0	10669	2709	31585
1995	0	199	0	11434	0	0	11633	2614	34199
1996	0	215	0	12461	0	0	12676	2543	36742
1997	0	233	0	13584	0	0	13817	2475	39217
1998	0	252	0	14804	0	0	15056	2408	41624
1999	0	272	0	16130	0	0	16402	2342	43966
2000	0	293	0	17582	0	0	17875	2299	46266
2001	0	315	0	19170	0	0	19485	2258	48524
2002	0	340	0	20893	0	0	21233	2217	50741
2003	0	366	0	22772	0	0	23137	2176	52917
2004	0	394	0	24821	0	0	25215	2137	55054
2005	0	424	0	27055	0	0	27479	2098	57152
2006	0	457	0	29490	0	0	29947	2060	59212
2007	0	492	0	32144	0	0	32636	2022	61234
2008	0	530	0	35037	0	0	35567	1985	63219
2009	0	571	0	38190	0	0	38761	1949	65169
2010	0	615	0	41627	0	0	42243	1914	67083

TOTAL LIFETIME PRESENT WORTH 67083

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : HIGH
SYSTEM : STEINMULLER

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	16610	0	0	0	0	0	16610	14699	14699
1986	18260	0	0	0	0	0	18260	14300	28999
1987	19052	0	0	0	0	0	19052	13204	42203
1988	0	365	2663	0	2235	0	5264	2857	45059
1989	0	395	2982	0	2353	0	5730	2728	47787
1990	0	426	3167	0	2334	0	5927	2475	50263
1991	0	460	3769	0	2521	0	6750	2473	52736
1992	0	497	4485	0	2723	0	7704	2498	55233
1993	0	537	5337	0	2940	0	8814	2529	57762
1994	0	582	6351	0	3176	0	10109	2567	60329
1995	0	630	6922	0	3382	0	10935	2457	62786
1996	0	682	7545	0	3602	0	11829	2373	65159
1997	0	737	8224	0	3836	0	12798	2292	67451
1998	0	798	8965	0	4085	0	13848	2215	69666
1999	0	860	9771	0	4351	0	14983	2140	71806
2000	0	927	10651	0	4656	0	16233	2088	73894
2001	0	998	11609	0	4981	0	17589	2038	75932
2002	0	1075	12654	0	5330	0	19060	1990	77922
2003	0	1158	13793	0	5703	0	20655	1943	79365
2004	0	1247	15035	0	6102	1	22384	1897	81762
2005	0	1343	16388	0	6530	1	24261	1852	83614
2006	0	1446	17863	0	6987	1	26296	1809	85423
2007	0	1558	19470	0	7476	1	28505	1766	87189
2008	0	1678	21223	0	7999	1	30900	1725	88914
2009	0	1808	23133	0	8559	1	33500	1685	90599
2010	0	1947	25215	0	9158	1	36320	1646	92244

TOTAL LIFETIME PRESENT WORTH 92244

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : EXISTING NO.2 OIL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0
1988	0	109	4299	0	0	16	4423	2401	2401
1989	0	117	4814	0	0	17	4948	2356	4757
1990	0	127	5112	0	0	19	5258	2196	6953
1991	0	137	6083	0	0	22	6242	2287	9239
1992	0	148	7239	0	0	25	7411	2403	11642
1993	0	160	8614	0	0	28	8802	2525	14167
1994	0	173	10251	0	0	32	10456	2655	16822
1995	0	187	11174	0	0	34	11395	2560	19383
1996	0	203	12179	0	0	37	12419	2492	21874
1997	0	219	13275	0	0	41	13536	2424	24299
1998	0	237	14470	0	0	44	14752	2359	26658
1999	0	256	15772	0	0	48	16077	2296	28953
2000	0	276	17192	0	0	53	17520	2254	31207
2001	0	297	18739	0	0	59	19095	2213	33420
2002	0	320	20426	0	0	65	20811	2173	35593
2003	0	344	22264	0	0	71	22680	2133	37726
2004	0	371	24268	0	0	78	24717	2095	39821
2005	0	400	26452	0	0	86	26937	2056	41877
2006	0	430	28833	0	0	92	29355	2019	43896
2007	0	464	31428	0	0	98	31990	1982	45879
2008	0	499	34256	0	0	105	34861	1946	47825
2009	0	538	37339	0	0	113	37990	1911	49735
2010	0	579	40700	0	0	121	41400	1876	51611

TOTAL LIFETIME PRESENT WORTH 51611

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : COAL OIL MIXTURE

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	7965	0	0	0	0	0	7965	6237	6237
1987	8562	0	0	0	0	0	8562	5934	12171
1988	0	217	2486	0	730	25	3459	1877	14049
1989	0	235	2784	0	768	28	3815	1816	15865
1990	0	254	2956	0	762	31	4003	1672	17537
1991	0	274	3518	0	823	35	4651	1704	19241
1992	0	296	4187	0	889	40	5412	1754	20995
1993	0	319	4982	0	960	45	6307	1809	22805
1994	0	347	5929	0	1037	51	7363	1870	24674
1995	0	375	6462	0	1105	55	7997	1797	26471
1996	0	406	7044	0	1176	60	8686	1743	28214
1997	0	439	7678	0	1253	66	9436	1690	29904
1998	0	475	8369	0	1334	72	10250	1639	31543
1999	0	512	9122	0	1421	78	11133	1590	33133
2000	0	552	9943	0	1521	85	12100	1557	34689
2001	0	594	10838	0	1627	95	13154	1524	36214
2002	0	640	11813	0	1741	105	14299	1493	37707
2003	0	689	12877	0	1863	115	15543	1462	39169
2004	0	742	14036	0	1993	126	16397	1432	40601
2005	0	799	15299	0	2133	138	18369	1402	42003
2006	0	861	16676	0	2282	148	19967	1373	43376
2007	0	927	18176	0	2442	159	21704	1345	44721
2008	0	999	19812	0	2613	170	23594	1317	46038
2009	0	1076	21595	0	2795	182	25649	1290	47328
2010	0	1159	23539	0	2991	195	27884	1263	48591

TOTAL LIFETIME PRESENT WORTH 48591

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : PLASMA ARC TOTAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	85391	0	0	0	0	0	85391	59180	59180
1988	0	101	1608	0	1272	66	3047	1654	60834
1989	0	110	1800	0	1364	73	3347	1593	62428
1990	0	118	1912	0	1428	80	3538	1478	63905
1991	0	128	2275	0	1539	92	4033	1478	65383
1992	0	138	2707	0	1635	104	4584	1486	66869
1993	0	149	3222	0	1395	117	4883	1401	68270
1994	0	162	3834	0	1506	133	5635	1431	69701
1995	0	175	4179	0	1604	144	6102	1371	71072
1996	0	189	4555	0	1708	157	6610	1326	72398
1997	0	205	4965	0	1819	171	7161	1283	73680
1998	0	222	5412	0	1938	187	7758	1241	74921
1999	0	239	5899	0	2064	204	8405	1200	76121
2000	0	257	6430	0	2208	222	9117	1173	77294
2001	0	277	7009	0	2363	248	9897	1147	78441
2002	0	299	7639	0	2528	273	10739	1121	79562
2003	0	322	8327	0	2705	299	11653	1096	80659
2004	0	346	9076	0	2894	328	12646	1072	81730
2005	0	373	9893	0	3097	360	13724	1048	82778
2006	0	402	10784	0	3314	386	14885	1024	83802
2007	0	433	11754	0	3546	414	16146	1000	84802
2008	0	466	12812	0	3794	443	17515	978	85780
2009	0	502	13965	0	4060	475	19002	956	86735
2010	0	541	15222	0	4344	509	20615	934	87669

TOTAL LIFETIME PRESENT WORTH 87669

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : PLASMA ARC PARTIAL

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	37898	0	0	0	0	0	37898	26265	26265
1988	0	106	2230	0	980	52	3368	1828	28093
1989	0	114	2497	0	1051	58	3720	1771	29865
1990	0	123	2652	0	1100	64	3939	1645	31510
1991	0	133	3155	0	1186	73	4547	1666	33175
1992	0	144	3755	0	1260	82	5241	1699	34875
1993	0	155	4469	0	1075	93	5792	1662	36536
1994	0	169	5318	0	1161	105	6752	1714	38251
1995	0	182	5796	0	1236	114	7329	1647	39897
1996	0	197	6318	0	1316	125	7956	1596	41493
1997	0	214	6886	0	1402	136	8638	1547	43041
1998	0	231	7506	0	1493	148	9378	1500	44541
1999	0	249	8182	0	1590	162	10183	1454	45995
2000	0	268	8918	0	1701	176	11064	1423	47418
2001	0	289	9721	0	1821	197	12027	1394	48812
2002	0	311	10596	0	1948	217	13071	1365	50176
2003	0	335	11549	0	2084	238	14206	1336	51513
2004	0	361	12589	0	2230	261	15441	1308	52821
2005	0	389	13721	0	2386	286	16783	1281	54102
2006	0	419	14956	0	2553	306	18235	1254	55357
2007	0	451	16302	0	2732	328	19814	1228	56584
2008	0	486	17770	0	2923	352	21531	1202	57786
2009	0	523	19369	0	3128	377	23397	1177	58963
2010	0	564	21112	0	3347	404	25427	1152	60115

TOTAL LIFETIME PRESENT WORTH 60115

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : NATURAL GAS

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	7722	0	0	0	0	0	7722	6047	6047
1987	8301	0	0	0	0	0	8301	5753	11800
1988	0	92	0	2816	0	0	2909	1579	13379
1989	0	100	0	3160	0	0	3260	1552	14931
1990	0	108	0	3494	0	0	3602	1504	16435
1991	0	116	0	3909	0	0	4025	1474	17910
1992	0	126	0	4369	0	0	4494	1457	19357
1993	0	136	0	4895	0	0	5030	1443	20810
1994	0	147	0	5476	0	0	5623	1428	22233
1995	0	159	0	5972	0	0	6131	1378	23615
1996	0	172	0	6508	0	0	6680	1340	24955
1997	0	186	0	7094	0	0	7280	1304	26259
1998	0	202	0	7731	0	0	7933	1269	27528
1999	0	218	0	8424	0	0	8641	1234	28762
2000	0	234	0	9182	0	0	9417	1211	29973
2001	0	252	0	10012	0	0	10264	1190	31163
2002	0	272	0	10912	0	0	11183	1168	32331
2003	0	293	0	11893	0	0	12185	1146	33477
2004	0	315	0	12963	0	0	13278	1125	34602
2005	0	339	0	14129	0	0	14469	1105	35707
2006	0	366	0	15401	0	0	15767	1084	36791
2007	0	394	0	16787	0	0	17181	1065	37856
2008	0	424	0	18298	0	0	18722	1045	38901
2009	0	457	0	19945	0	0	20402	1026	39927
2010	0	492	0	21740	0	0	22232	1007	40934

TOTAL LIFETIME PRESENT WORTH 40934

06/07/84

FOSSIL STATION
IGNITION SYSTEM STUDY

IN K DOLLARS PRESENT WORTH TO 1984 01

STATION : NANTICOKE
SCENARIO : LOW
SYSTEM : STEINMULLER

	CAPITAL	OM & A	COST OF OIL	COST OF GAS	COST OF COAL	COST OF ELEC	TOTAL	PRESENT WORTH	CUMUL. P WORTH
1984	0	0	0	0	0	0	0	0	0
1985	16610	0	0	0	0	0	16610	14699	14699
1986	18260	0	0	0	0	0	18260	14300	28999
1987	19052	0	0	0	0	0	19052	13204	42203
1988	0	292	1322	0	1200	0	2814	1528	43730
1989	0	316	1480	0	1264	0	3059	1457	45187
1990	0	341	1571	0	1254	0	3166	1322	46509
1991	0	368	1870	0	1354	0	3592	1316	47825
1992	0	398	2225	0	1462	0	4085	1324	49149
1993	0	429	2648	0	1579	0	4657	1336	50486
1994	0	466	3151	0	1706	0	5323	1352	51837
1995	0	504	3435	0	1817	0	5756	1293	53130
1996	0	545	3744	0	1935	0	6224	1249	54379
1997	0	590	4081	0	2061	0	6732	1206	55585
1998	0	638	4448	0	2195	0	7281	1164	56749
1999	0	688	4848	0	2337	0	7874	1124	57874
2000	0	741	5285	0	2501	0	8527	1097	58971
2001	0	798	5760	0	2676	0	9235	1070	60041
2002	0	860	6279	0	2863	0	10002	1044	61085
2003	0	926	6844	0	3064	0	10834	1019	62104
2004	0	997	7460	0	3278	0	11736	995	63099
2005	0	1074	8131	0	3507	0	12714	971	64069
2006	0	1157	8863	0	3753	0	13774	947	65017
2007	0	1246	9661	0	4016	1	14923	925	65941
2008	0	1342	10530	0	4297	1	16170	903	66844
2009	0	1446	11478	0	4598	1	17522	881	67725
2010	0	1558	12511	0	4919	1	18989	860	68585

TOTAL LIFETIME PRESENT WORTH 68585

APPENDIX VI

Other Ignition Possibilities

(a) Combustion Engineering Revised System

During the course of the study, it became evident that Combustion Engineering system as offered to Ontario Hydro at Lambton GS was not viable. This information was passed to Combustion Engineering informally to see if anything could be done.

Combustion Engineering did come up with a a new system. However, it was conceptual only as Combustion Engineering felt that further effort could not be justified at this time due to the limited ignition fuel requirement for Lambton GS.

Elements of the original scheme are used, in that pulverized coal is drawn off a pulverizer and passed to a cyclone arrangement where the coal is collected. This coal is then available for dense phase transport to any boiler for ignition purposes. The dense phase transport is achieved in the same manner as the original system - coal pumps and compressed air passing the coal via diverters to the igniters. Three levels of these igniters would be supplied. In this respect the igniter would really be warm up guns as the side igniters would still be required to bring on pulverizers on most occasions.

No pulverized coal storage is considered for this scheme (other than the cyclone capacity) and this considerably lowers the installation cost. The pulverizer supplying the coal for ignition is either one from an operating unit or one which is heated to normal operating temperature by a duct heater.

Many aspects of the revised system are conceptual and have not gone through a detailed engineering analysis. However Combustion Engineering believe that the total capital cost of the revised system would only be 25 percent of that for the original system described in Section 5 of this study.

(b) Foster Wheeler Approach

Foster Wheeler are somewhat reluctant to discuss their system - probably due to lack of operating experience - therefore, only a general outline can be given.

Gibson GS, Mount Carmel, Illinois, is the only commercial sized installation considered to date that we are aware of. However, as of April 1984, the system is not yet in place.

The Foster Wheeler approach is to modify one pulverizer and its associated burners so that coal can be fired in small quantities - low load nozzles. In order to maintain flame, small oil igniters are also fired, these igniters are an integral part of the low load coal nozzles. Presumably some oil firing is also carried out to preheat the pulverizer air.

(c) Electrical Heaters in Primary Air Ducts

One approach to reduce the high ignition oil consumption at Nanticoke GS could be to use electrical elements in the primary air ducts to one or two pulverizers. This has been done before using oil. However (in Ontario) there is now a good case for considering electrical heating. Lower energy costs would be incurred, the system would be cheaper to install and almost certainly would be more reliable. Depending on the type of heating surface used it could be argued that the system would also be safer from fire risks, etc.

Two other changes would also be required to effect a transition in ignition. The pulverizer control would need to be adapted to permit operation at about 20 percent of design rated output. Finally, the ignition oil burners on the low output capability pulverizers would also have to be capable of operating at about 25 percent of the present rate of ignition firing. This latter aspect not only reduces the cost of the igniton oil required, but maintains a similar ignition firing rate to that used at present.

(d) Central Coal Pyrolysis Plant

A late proposal by the Ontario Hydro Research Division is to install a coal pyrolysis plant which could manufacture a gaseous ignition fuel. For economic reasons this would be a central plant with gas storage facilities. Coal would be pyrolyzed on a more or less continuous basis (possible shutdown during system load peaks) the resultant gas being stored for ignition on demand.

There is little doubt regarding the technical feasibility of this approach. However, from preliminary findings of plasma arc pyrolysis, it is thought that the process would probably be too energy intensive for economic viability. There remains of course, the aspect of possible total oil elimination. This may be seen someday, as sufficient reason to overrule marginal economic difficulties.